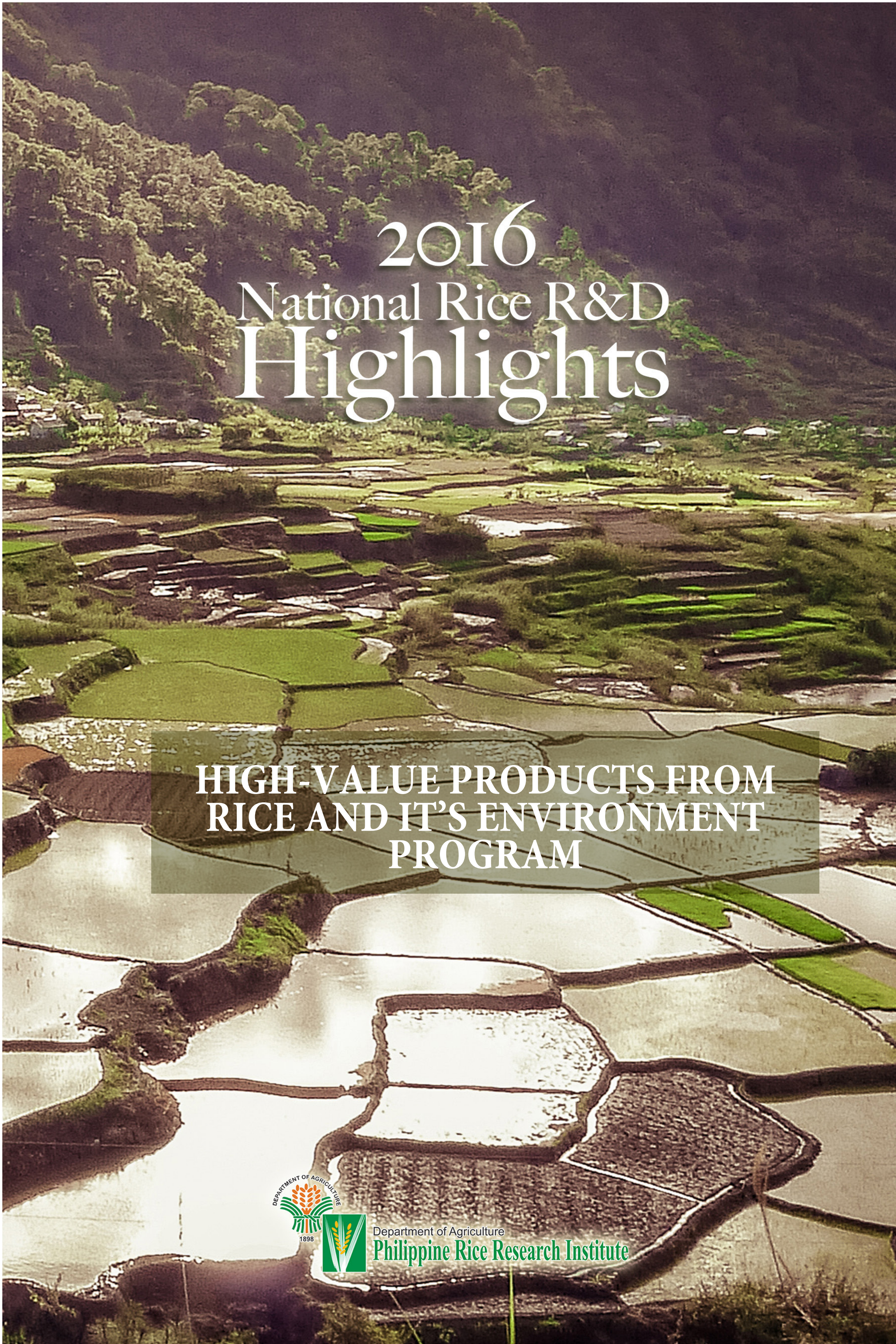

2016 National Rice R&D Highlights

HIGH-VALUE PRODUCTS FROM RICE AND IT'S ENVIRONMENT PROGRAM

DEPARTMENT OF AGRICULTURE 1898
Department of Agriculture
Philippine Rice Research Institute

TABLE OF CONTENTS

High-Value Products From Rice and its Environment Program (HVP)

Program Leader: Marissa V. Romero

Executive Summary

Rice remains to be the staple food in the Philippines that's why it is still the country's major crop. The most commonly consumed form is milled or white rice, which serves as the main source of carbohydrates for daily energy requirement. However, there are other forms or kinds of rice such as brown rice, pigmented rice, and micronutrient-dense rice that offer additional health benefits. In addition, there are specialty rice including aromatic and glutinous rice that command higher price in the market. The use of suitable rice varieties and appropriate crop management will encourage the farmers to cultivate these kinds of rice for higher profitability.

Although utilized mostly as table rice in boiled form, rice can also be processed into various products. The different forms of rice such as rough rice, unpolished rice, milled rice, brokens, rice flour, and rice starch can be converted into many nutritious and marketable food products. These value-adding activities for rice can improve the nutritional status of consumers and can also enhance the profitability of rice farming by providing additional income to the different rice stakeholders.

The High-Value Products from Rice and Its Environment (HVP) Program explores rice and other crops in the rice environment to help increase the income and improve the nutritional status of the members of the rice farming community. Value-adding systems are developed to bring about enhancement of quality, nutrition, shelf-life, market value, profitability, and availability of rice, other crops, and products from organisms in the rice environment to benefit the rice farmers and industry stakeholders.

In 2016, the HVP Program implemented two projects: High-Value Rice Grain and High-Value Products from the Rice Grain and Other Parts of the Rice Plant. The first project focused on the development of healthy and nutritious gamma-aminobutyric acid (GABA) rice from Philippine rice cultivars for potential applications to food and pharmaceutical industries; quality evaluation of micronutrient-dense rice; exploration of the potential of other crops in the preparation of nutrient-rich rice blends with high consumer acceptability; development and/or verification of pre-harvest and post-harvest management options for aromatic and organic rice; and isotopic fingerprints.

Meanwhile, the objectives of the second project include the following: to explore and evaluate the potential of developing high-value

products derived from the rice grain, rice plant parts and rice cell/organ cultures; to innovate from existing and/or develop high-value product prototypes, processes and technologies utilizing the other parts of the rice plant and/or rice cell/organ cultures as main sources; to characterize the material sources and developed products, processes and technologies and other relevant materials involved in the process; to develop production systems/protocols for high-value products from the rice grain, other rice plant parts and rice cell/organ cultures, to evaluate the bio-efficacy, clinical and toxicological properties and marketability of selected high-value products, processes and technologies developed.

I.High-Value Rice Grain

Project Leader: MV Romero

In the Philippines, rice is the most important part of the diet because it is the staple food of its population. Thus, rice serves as the primary source of calories needed for the daily energy requirement of Filipinos. It also provides a significant amount of protein to those who cannot afford to buy protein-rich foods such as meat and fish. Majority of Filipinos prefer to eat cooked milled or polished rice because of its excellent eating quality. Unfortunately, milled rice contains mostly carbohydrates and protein since most of the micronutrients are removed during the milling process.

There are other forms and types of rice with added value and health benefits. Brown rice or the unpolished form of rice has more health benefits than milled rice because of higher amounts of dietary fiber, fat, vitamins, minerals, and antioxidants. There is also germinated or sprouted brown rice which contains γ-amino butyric acid (GABA). This form of rice is more nutritious, softer, sweeter, and tastier compared to brown rice. The persistent problem of micronutrient deficiency in the country has prompted various interventions such as commercial fortification and biofortification to enhance the amounts of iron and zinc in rice. Since the Philippines is rich in nutrient-dense crops, they can also serve as alternative staple foods. Efforts are being made to incorporate other staples in the regular diet by substituting them to rice as the main item of the meal. As most consumers are not yet accustomed to eating them as total replacement to table rice, alternative staples may be mixed with rice in certain proportions that would satisfy consumer requirements on eating quality, nutritional improvement, and hunger mitigation. Aromatic and organic rice, which command higher market value, are also becoming popular nowadays.

This project evaluated germinated brown rice, micronutrient-dense rice, nutrient-rich rice blends, aromatic rice, and organic rice which have added value and/or health benefits compared to the regularly milled rice.

The general objectives include: (1) development of healthy and nutritious GABA rice from Philippine rice cultivars and identification of their potential applications to food and pharmaceutical industries; (2) determination of the grain quality and acceptability of commercially-fortified and biofortified raw and cooked iron- and zinc- rice; (3) exploration of the potential of corn and adlai in the preparation of nutrient-rich rice blends with high consumer acceptability; (4) development/verification of pre-harvest and post-harvest management for aromatic and organic rice; and (5) isotopic fingerprints.

Healthy and nutritious GABA rice for functional food and pharmaceutical industries

RMBulatao, MBCastillo, RPTubera, JPASamin, BSPeralta, and MVRomero

Gamma-amino butyric acid (GABA) is currently one of the most promising compounds due to its health-promoting and cognitive-enhancing properties. It is a non-protein amino acid that serves as neurotransmitter in the central nervous systems. Regular intake of GABA-rich foods or supplements is effective in stimulating immune system and is helpful in treating insomnia, mental irritation, depression, and other neurological disorders. In rice, GABA is found to lower blood pressure, inhibit leukemia cell proliferation, and stimulate cancer cell apoptosis. Because of these, GABA rice is being consumed as a staple food and widely marketed as functional foods in Japan, China, Korea, Malaysia, and Thailand. It is used as ingredient in making bread, cookies, crackers, rice balls, rice burger, and instant GABA rice drink. Unfortunately, GABA rice has not yet explored in the country given that we have plenty of potential rice cultivars for the production of this novel food stuff. Therefore, this study evaluated the potential of Philippine rice cultivars in the production of healthy and nutritious GABA rice for functional food and pharmaceutical products.

Activities:

- Brown rice (BR) form of NSIC Rc160 was used to produce healthy and nutritious GABA rice. BR was soaked for 0, 12, 24, 36, and 48h and subjected to different drying methods (sun-drying at 35-50°C for 24h; oven-drying at 60°C for 12h; and freeze-drying at -20°C for 24h). After reaching the 12% moisture content, all GABA rice samples were placed in the aluminum bag, sealed and keep in the refrigerator at 4°C prior to chemical analyses and sensory evaluation.

- GABA rice samples were evaluated for the chromametric (L* and b*) values and proximate compositions (moisture, ash, protein, and fat contents).

- Raw and cooked forms of GABA rice samples were assessed for their sensory properties (Raw: aroma, fermented-odor, rancid-odor, color, glossiness and hardness; cooked: aroma, fermented-odor, rancid-odor, color, glossiness, cohesiveness, tenderness, taste, and off-taste) and general acceptability.

- Phytic acid content of GABA rice samples was determined using the modified acid extraction colorimetric method.

- GABA content of rice samples was determined using an Ultra Performance Liquid Chromatography. Rice samples were extracted with 70% ethanol and the GABA was derivatized using a derivitization kit (Waters, Singapore) purchased from RainPhil Incorporated. The GABA was separated in a sample matrix using a linear gradient system consisting of 0.1% formic acid in acetonitrile (mobile phase A) and acetonitrile (mobile B). The GABA was passed through a C-18 reverse phase column and was detected using photodiode array at 330nm.

- Antidiabetic potential of GABA rice was evaluated using an alloxan-induced diabetic rats at Pampanga S. GABA rice from three different varieties, namely, NSIC Rc13, Rc160, and Rc152 were fed daily to rats for 35 days. Blood glucose level was measured at 0, 14, 21, 28, and 35 days.

- Instant GABA rice congee is being developed in collaboration with the Institute of Food Science and Technology, UPLB.

Results:

- Chromametric values of GABA rice samples were quantitatively determined using a Konica Minolta CM-5 spectrophotometer. These parameters measure the intensity of lightness (+L*) and yellowness (+b*) of rice samples after soaking and drying. The L* value of rice samples increased up to 36h and then slightly decreased at 48 h for all the drying methods. Opposite trend was observed for the b* value of GABA rice samples wherein it decreased up to 36 h and then slightly increased at 48 h of soaking.

- Regardless of drying method used, the ash and protein contents of GABA rice samples significantly increased upon soaking up to 48h. The fat content increased after 24h but gradually decreased after 48h. The moisture (10.7 to 11.8%) and protein (8.2-8.4%) contents of rice samples were not affected by soaking time and drying methods.

- In general, the sensory properties of GABA rice samples were not significantly affected by different soaking times and drying methods soaking (Figures 1 and 2). Of the three drying methods, oven-drying showed slight improvement in sensory qualities and general acceptability. Overall, BR soaked for 48h and oven-dried at 60°C for 12h produced the GABA rice with best eating quality.

- Retention time of GABA was found to be at 5.78min. BR sample soaked for 48h produced the highest GABA content (16.56mg/100g), which is six times higher than the unsoaked sample (2.74mg/100g) (Figure 3).

- Phytic acid content of GABA rice samples decreased by 35% after 48h of soaking (Figure 4).

- Blood glucose levels of diabetic rats fed with GABA rice were significantly reduced from 292-342 mg/dl to 54-127 mg/dl, which is equivalent to 57 to 84% reduction after 35 days of feeding. Furthermore, the blood glucose level of all diabetic rats became normal (<150mg/dl) after feeding of GABA rice for 35 days.

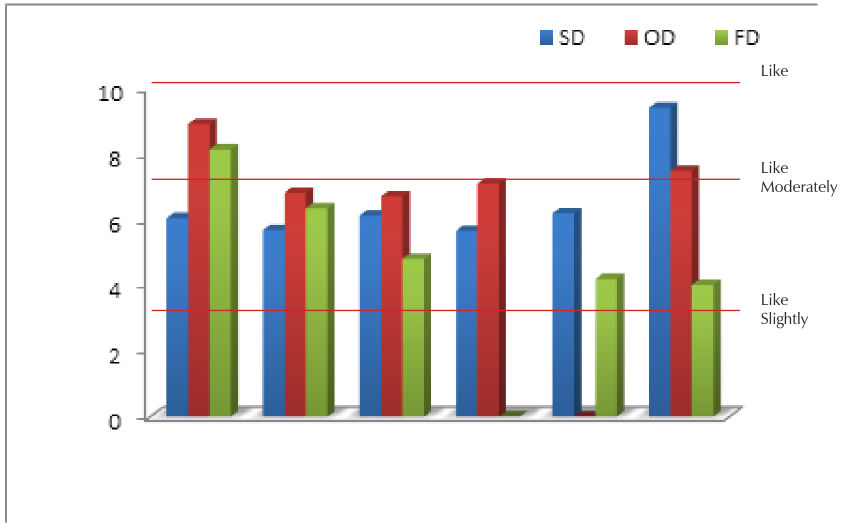

Figure 1. Acceptability score of raw GABA rice samples at different soaking times.

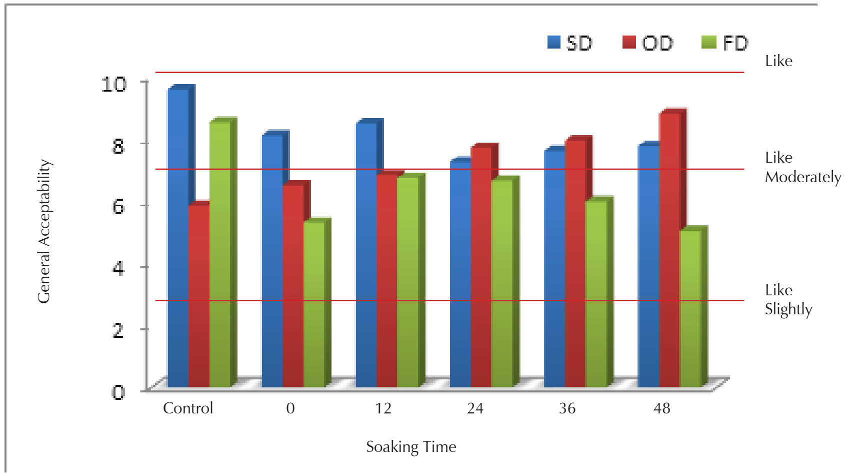

Figure 2. Acceptability score of cooked GABA rice samples at different soaking times.

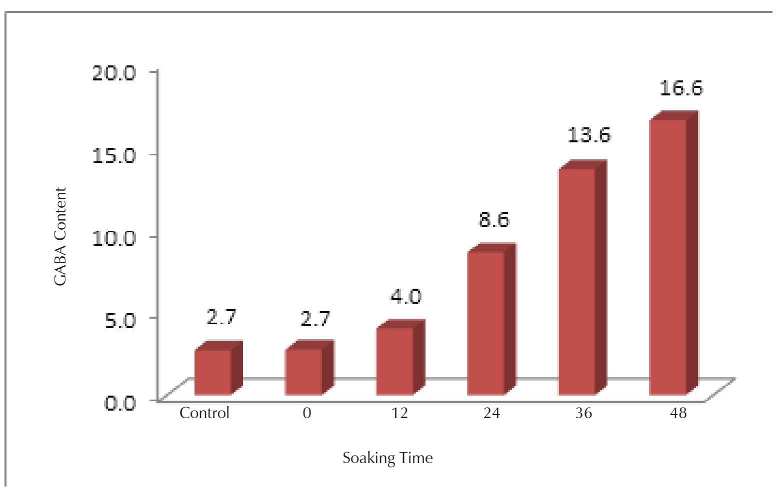

Figure 3. GABA content (mg/100g) of oven-dried GABA rice samples at different soaking times.

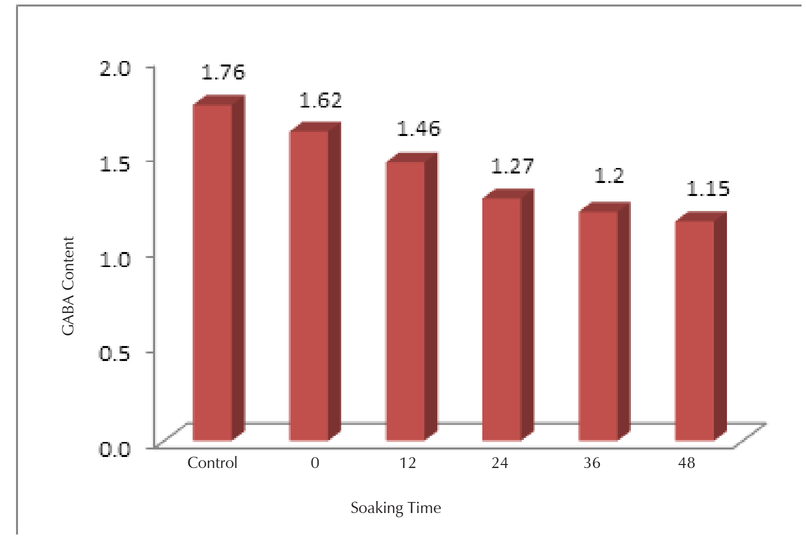

Figure 4. Phytic acid content (mg/100g) of dried GABA rice samples at different soaking times.

Quality assessment of iron- and zinc-dense rice

RG Abilgos-Ramos, JPA Samin, EC Arocena, and OC Soco

Breeding for high iron and zinc rice is still on as iron-deficiency anemia and zinc deficiency are still prevalent among children, and pregnant and lactating women. This study assessed the field performance in terms of yield of rice lines bred for iron and zinc content, the grain quality in terms of milling potential, physical attributes, and physicochemical properties, and the mineral concentration of unpolished and polished rice materials. Data on yield, grain quality properties, and mineral concentration of these breeding lines are important in identifying the potential lines for release as high iron and zinc rice variety.

Activities:

- Thirty-eight breeding lines of biofortified rice (iron and zinc) were seed increased in 2016 DS.

- A total of 43 2015 WS biofortified rice lines from PhilRice plant breeders were analyzed for grain quality properties and mineral concentration. Parameters such as milling potential, physical properties, and physicochemical properties of each rice line were evaluated to assess their grain qualities and acceptability. Iron and zinc contents were also determined using the Atomic Absorption Spectroscopy. The 31 2016 DS materials are currently being evaluated for their grain quality parameters.

Results:

- Yield performance of the top 10 2016 DS entries ranged from 8276kg/ha to 9356kg/ha with a yield advantage over MS 13 of 28.1% to 44.9% (Figure 5). Nine other entries had yields ranged from 6841kg/ha to 8112kg/ha also out-yielded MS 13 (6459kg/ha) by 5.9% to 25.6%. Moderate to severe infestation/infection of bacterial leaf blight, sheath blight, and stemborer was observed on some entries.

- The moisture content (MC) of the 2015 WS rough rice samples ranged from 9.60 to 11.90%. All rice samples had fair brown rice (BR) recovery except for PR43888-3B-8-2 which had a poor BR recovery. Also, PR43888-3B-8-2 had a G2 milled rice (MR) recovery, which failed to pass the recommended values. On the other hand, all the samples had grade 1 to premium MR recovery. In terms of head rice recovery, the rice line samples had a range of 28.4% to 59.6%, wherein 46.5% (20 rice lines) passed the recommended values.

- In terms of their physical dimensions, 74.4% (32 rice lines) of the 2015WS biofortified rice lines had long and slender grains, 11.6% (5 rice lines) with long and intermediate grains, while the remaining 14% comprised of medium and intermediate-shaped grains. The % chalky grains of the rice lines ranged from grade 3 (62.6%) to premium (1.6%) in which 46.5% (20 rice lines) passed the recommended value of 5% and less for chalky grains.

- The MC of the biofortified rice lines harvested during the 2015 wet season ranged from 10.9 to 11.8%.

- The amylose content of the rice samples ranged from 7.7% to 25.6%. 19 rice lines (44.2%) had intermediate amylose content (AC), which is the most preferred by consumers. It was followed by 12 rice lines (27.9%) with low amylose content, 11 (25.6%) with high AC, and 1 rice line (2.3%) with very low amylose content. Their gelatinization temperature as measured by alkali spreading values suggested low to high intermediate classification. Furthermore, the crude protein content of the rice lines ranged from 5.6% to 8.1%, wherein only PR43909-B-10-1-2 had not pass the recommended range of values for protein (6%-9%).

- The iron and zinc contents (Table 1, Figures 6 and 7) of the unpolished form of the 43 rice lines ranged from 10.20 mg/Kg (PR43156-3B-3-1-3) to 74.79 mg/Kg (PR43909-B-7-1-3) and from 12.22mg/Kg (PR40228-(Fe)-2B-B-38-1-4-1-NEW) to 25.99mg/Kg (PR38982-(Fe)-5B-5-1-1-1-1). Moreover, PR40228-(Fe)-2B-B-38-1-4-1-NEW had the highest iron content among the rice lines in polished form. On the other hand, 65.12% (28 rice lines) obtained lower than 5mg/Kg of iron (the lower limit of detection of the equipment used in the analysis). Zinc content of the rice lines in polished form ranged from 9.11mg/Kg (PR43909-B-10-1-2) to 38.89 mg/Kg.

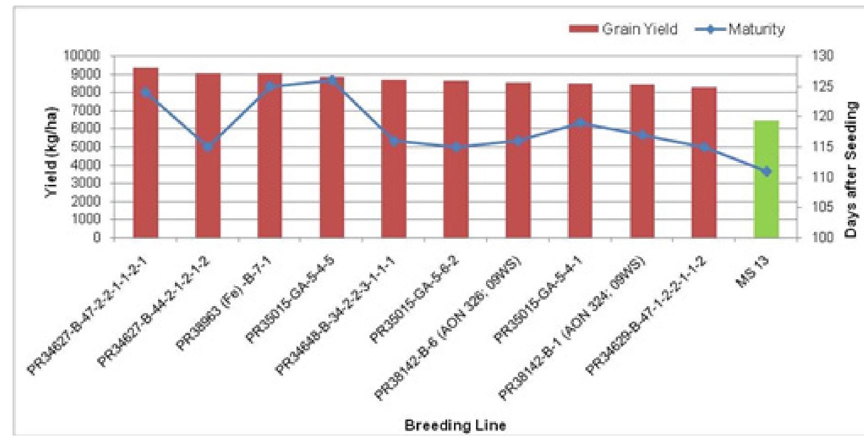

Figure 5. Yield performance of the top 10 high Fe/Zn advanced lines for seed increase, 2016DS.

Table 1. Micronutrient content of 43 breeder rice lines (2015WS).

Entry No.	Designation	Unpolished Rice		Polished Rice	
		Fe Content (mg/kg) ± SD	Zn Content (mg/kg) ± SD	Fe Content (mg/kg) ± SD	Zn Content (mg/kg) ± SD
AON 75	PR43156-3B-3-1-3	10.20±0.19	21.07±0.59	14.92±0.40	20.67±0.56
AON 78	PR43156-3B-8-1-2	11.67±0.54	20.46±1.34	9.59±0.51	16.71±0.67
AON 82	PR43996-2B-56-1-1	13.11±0.42	22.78±2.23	<5.00	38.89±0.20
AON 68	PR44930-2B-13	11.97±1.16	20.66±2.09	<5.00	19.52±0.89
AON 69	PR44930-2B-17	21.94±5.55	18.26±0.47	<5.00	28.88±1.27
AON 70	PR44930-2B-18	17.28±1.19	19.54±0.63	<5.00	18.83±0.51
AON 72	PR43888-3B-8-2	17.31±0.79	22.19±0.11	<5.00	23.56±1.13
AON 76	PR43156-3B-3-3-1	19.38±0.78	18.17±0.69	<5.00	20.99±0.98
AON 77	PR43156-3B-8-1-1	21.36±1.31	16.97±0.69	<5.00	25.71±0.53
AON 79	PR43908-2B-46-1-2	20.33±1.22	20.76±1.02	<5.00	32.02±1.10
AON 81	PR43996-2B-44-2-3	24.93±1.62	23.25±1.01	<5.00	23.29±1.30
AON 83	PR40282-(Fe)-2B-8-2-2-1-1-2-1-2-1	28.27±0.99	22.89±1.20	<5.00	18.93±0.40
AON 84	PR40282-(Fe)-2B-8-2-2-1-1-2-1-2-2	19.33±0.63	14.20±1.05	<5.00	21.54±0.80
AON 86	PR40228-(Fe)-2B-B-26-1-1-1-2-1	31.52±2.85	23.03±1.21	<5.00	29.10±1.43
AON 136	PR43872-JR-2B-1-1	40.13±2.38	15.99±0.70	<5.00	19.90±1.01
AON 138	PR43872-JR-2B-11-1	18.17±2.81	16.56±1.96	<5.00	19.16±0.96
PYT 57	PR38963 (Fe)-B-5-5-1	29.06±1.79	21.66±2.48	<5.00	24.34±1.16
PYT 44	PR41079-(Fe)-B-B-14	24.35±4.03	18.04±2.43	<5.00	16.33±0.53
PYT 45	PR40228-(Fe)-3B-38-2-2-1-1	20.08±0.54	24.45±1.56	<5.00	23.14±1.10
PYT 46	PR40241-(Fe)-4B-12-2-1-1	21.38±0.49	24.51±0.70	<5.00	16.85±0.65
PYT 47	PR38982-(Fe)-5B-5-1-1-1-1	32.58±1.00	25.99±0.77	<5.00	22.91±0.56
PYT 53	PR40228-(Fe)-2B-B-42-1-1	20.55±1.44	25.02±1.77	<5.00	17.68±0.98
PYT 55	PR40228-(Fe)-2B-B-11-1	18.09±1.24	23.73±1.17	<5.00	18.92±0.41
PYT 59	PR38952-B-22-3-2	16.65±0.22	24.17±0.59	<5.00	21.55±0.76
PYT 64	PR44031-(Fe)-2B-2	24.4±0.59	21.73±0.46	<5.00	28.53±1.30
PYT 60	PR40225-(Fe)-2B-6-2-2-2-1	20.16±0.62	23.43±0.19	<5.00	14.06±0.76
PYT 61	PR44026-2B-2	20.13±1.12	24.61±2.26	<5.00	28.51±1.07
PYT 63	PR44026-2B-9	20.55±1.75	23.75±2.28	<5.00	23.26±1.48
PYT 65	PR44031-2B-15	35.16±1.56	21.44±1.24	<5.00	25.89±0.85
PYT 68	PR43156-3B-3-3	33.02±2.59	18.54±0.38	<5.00	13.59±0.40
PYT 69	PR43996-2B-39-2	24.09±0.18	19.37±0.97	11.48±0.58	21.33±0.83
PYT 70	PR44026-2B-6-1	24.73±0.83	19.71±0.35	8.30±0.73	13.20±0.61
PYT 71	PR44026-2B-6-2	17.84±0.51	19.87±0.44	10.57±0.71	12.50±0.41
PYT 72	PR44031-2B-6-2	40.12±1.21	17.71±0.92	10.82±1.54	9.90±0.27
PYT 73	PR44031-2B-16-1	27.26±0.40	16.52±0.94	8.20±0.72	11.21±0.62
PYT 74	PR44031-2B-21-1	21.50±1.45	17.29±0.60	13.96±0.46	10.92±0.29
PYT 75	PR40282-(Fe)-2B-8-2-2-1-2-1-1-3	53.97±3.49	22.64±1.30	13.07±1.17	9.25±0.21
PYT 76	PR43909-B-7-1-3	74.79±2.14	22.02±0.48	9.00±0.58	11.18±0.60
PYT 77	PR43909-B-10-1-2	29.46±0.95	18.76±0.50	10.87±0.69	9.11±0.31
PYT 78	PR43913-B-7-1-2	52.96±2.07	16.85±0.49	18.07±1.43	18.30±0.95
PYT 80	PR43229-3B-42-1	57.45±1.77	17.56±0.86	14.79±0.44	11.17±0.37
MYT 67	PR40228-(Fe)-3B-38-2-1-1-1 (NEW)	42.35±3.12	14.64±1.23	12.65±0.89	10.71±0.72
MYT 68	PR40228-(Fe)-2B-B-38-1-4-1 (NEW)	27.73±1.40	12.22±0.53	19.79±1.60	20.35±1.97

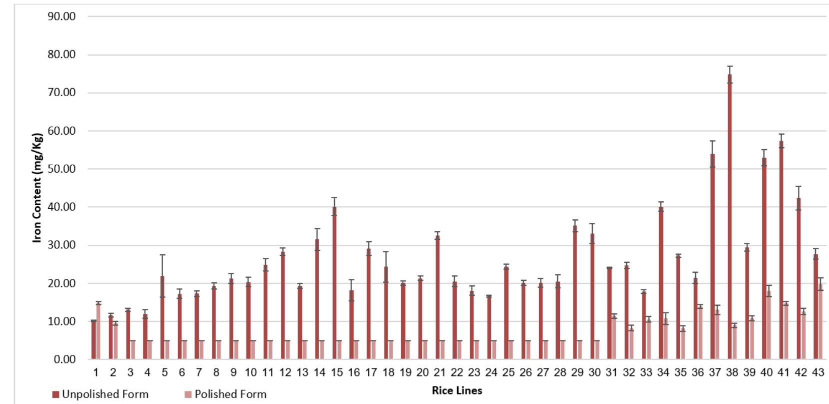

Figure 6. Iron concentration of the rice lines (2015WS).

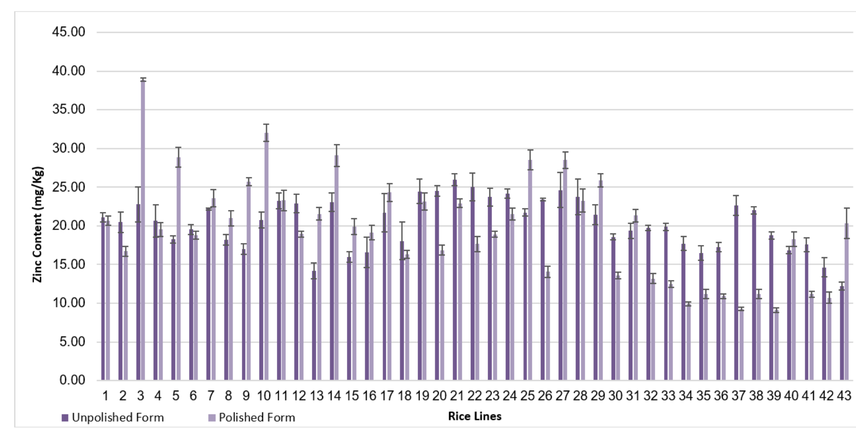

Figure 7. Zinc concentration of the rice lines (2015WS).

Development of nutrient-rich rice blends using local food crops

HF Mamucod, RV Manaois, AV Morales, and MV Romero

Adlai (Coix lacryma-jobi L. var. ma-yuen) and corn (Zea mays) have recently been promoted as alternatives to rice as a measure to help control the increasing per capita intake of rice in the Philippines. Adlai or "katigbi" is grown and eaten mostly in Southern Philippines, particularly in Zamboanga del Sur (Dela Cruz, 2011). Nutritional value of adlai was reported to be comparable, or even better, than rice. It provides around the same amount of energy as milled rice (Juliano, 2003) at 356kcal per 100g, but its protein and total fat content were higher (Adlai, n.d., Dechkunchon and Thongngam, 2007). On the other hand, corn, specifically the white variety of Quality Protein Maize (QPM) has acceptable taste similar to rice alone. QPM is nutritionally superior to ordinary white corn in terms dietary fiber and minerals. It also contains two essential amino acids, lysine and tryptophan. Considered as low GI food, QPM has higher amylose content which makes it harder to gelatinize and slower to digest compared with rice. This study evaluated the suitability of adlai and QPM in complementing rice as staple food and in the development of energy bar and ready-to-eat rice:adlai and rice:corn blends.

Activities:

Energy bar

- Adlai var gulian, unpolished and polished NSIC Rc222, unpolished Chro-chor-os, and unpolished Ittum were puffed and used in the development of energy bar (Figure 8). Puffing of samples was done in Tayug, Pangasinan (Figure 9). Nutritional composition (moisture content, total sugar, crude ash, crude fat, crude protein, and total dietary fiber) of the product was evaluated.

- Shelf-life of energy bar made with puffed adlai and unpolished NSIC Rc222 was evaluated. The samples were packed in polypropylene and aluminum-coated pouches and stored at ambient temperature (25.6 to 28.2^{o}C, 41 to 62% relative humidity) (Figure 10). Periodic evaluation of sensory properties, water activity, moisture content, and microbial load was performed.

Ready-to-eat rice:adlai and rice:corn blends

- Several DA regional offices and centers (STIRAC, CVIARC, BIARC, and DA-MIMAROPA) were coordinated and requested for adlai samples. Adlai var ginampay is also being cultivated at the Future Rice farm.

- Using the previously identified rice variety and the established rice:adlai and rice:corn ratios, read-to-eat rice:adlai and rice:corn blends were prepared by retorting using polyethylene retort pouch (Figure 11). Retorting was done using the newly acquired Automatic Autoclave (Model CL-32/42 Series, ALP Co. Ltd., Tokyo, Japan). The effect of different volume of water, soaking, and steaming on the physical appearance and texture of the retort-processed products was evaluated.

Results:

Energy bar

- Samples made with puffed pigmented rice (Chor-chor-os and Ittum) had higher fat content compared with those made with non-pigmented NSIC Rc222. Energy bar made with unpolished rice, regardless of the variety, contained significantly higher fiber content than that made of polished rice. Sample with unpolished NSIC Rc222 had the highest ash content among the sample (Table 2).

- Preliminary result of sensory evaluation showed that the energy bar generally remained stable and acceptable after four weeks of storage regardless of the packaging materials used. However, there was a slight decrease in cohesiveness and chewiness on the second week of storage compared with the freshly prepared sample. Moisture content and water activity of the samples ranged from 8.37 to 8.81% and 0.48 to 0.51, respectively. In terms so microbial load, all the samples were within the safe level of aerobic plate (105cfu/g) and mold (102cfu/g) counts. Yeast was not detected in all samples.

Ready-to-eat rice:adlai and rice:corn blends

- Soaking the rice:adlai and rice:corn blends for 30min prior to processing produced better texture and consistency of the retort-processed blends. Steaming for 30 min also improved the quality of the products. The optimum water volume for rice:adlai and rice:corn were 50 and 60mL, respectively.

- Retorting did not produce significant effect on the color and texture (cohesiveness and tenderness) of the retort-processed rice:adlai blend compared with the pan-cooked sample. However, pan-cooked sample was glossier than the retort-processed one.

- Retort-processed rice:corn blend had comparable gloss and texture (cohesiveness and tenderness) with the pan-cooked sample.

Figure 8. Energy bar made with puffed rice and adlai.

Figure 9. Puffing of rice and adlai.

Figure 10. Rice:adlai energy bar packed in PP and aluminum-coated pouches stored at room temperature.

Figure 11. Ready-to-eat (retort-processed) rice:adlai and rice:corn blends.

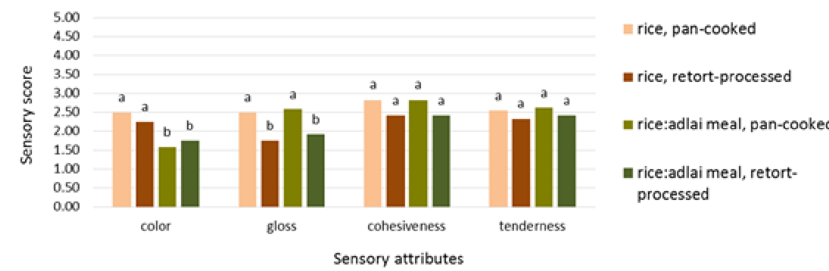

Figure 12. Sensory characteristics of ready-to-eat rice:adlai blend.

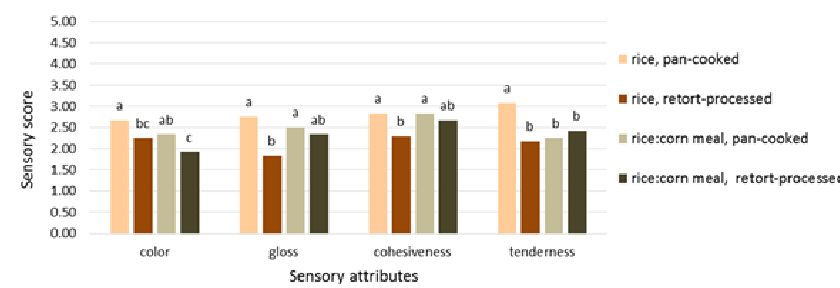

Figure 13. Sensory characteristics of ready-to-eat rice:corn blend.

Table 2. Nutritional composition of rice-adlai energy bar*.

NUTRITIONAL PROPERTIES	ENERGY BAR WITH PUFFED RICE-ADLAI			
	Polished NSIC Rc222:adlai	Unpolished NSIC Rc222:adlai	Unpolished Chor-chor-os:adlai	Unpolished Ittum:adlai
Moisture content (%)	8.64^{b}	9.24^{a}	9.31^{a}	8.69^{b}
Total sugar as invert (%)	51.39^{a}	51.38^{a}	50.09^{a}	49.88^{a}
Ash (%)	1.44^{b}	**1.48^{a}**	1.44^{b}	1.42^{b}
Crude fat (%)	23.50^{b}	23.29^{b}	23.93^{a}	23.76^{a}
Crude protein (%)	9.20^{a}	9.23^{a}	9.27^{a}	9.24^{a}
Total dietary fiber (%)	1.62^{b}	**1.94^{a}**	1.74^{ab}	2.07^{a}

**Mean values with the same letter within a row are not significantly different at p=0.05 (n=2)*

Pre-harvest and post-harvest management for aromatic and organic rice

MAU Baradi, MC Quimbo, JM Solero, MS Cabrera, MFA Magno, RG Ancheta, CT Dangcil, RT Cruz, MJC Regalado, and MV Romero

Aromatic and organic rice have become popular and continue to command higher price in the market. Aromatic rice is preferred by consumers because of its distinctive pleasant scent that makes it more special than the ordinary rice. The major compound identified to give rice its pandan- or popcorn-like scent was the 2-acetyl-1-pyrroline or 2AP (Buttery et al. 1983; Paul and Powers 1989). The scent of aromatic rice is inherent in the variety, but can be influenced by pre-harvest and post-harvest management practices.

Organic rice or organically-grown rice has also become popular among consumers because of the belief that it has more nutritional benefits (Tafere et al. 2011). Organic rice is grown only with organic amendments/materials/fertilizers and bio-pesticide. The benefit of organic material is that they may contain several essential nutrients (IRRI 2013). However, the organic fertilizer releases nutrients much slower than inorganic (mineral) fertilizers like ammonium sulphate and urea. Thus, the response of plants to organic fertilizer is likewise delayed because these materials have to be mineralized first before the nutrients can be taken up by the plant.

In addition to the usual Palaycheck System Key Check 1 (seed quality) to Key Check 7 (pest management), the recently-improved Key Check 8 (harvest management) and the proposed Key Check 9 (post-harvest management) was initially validated for aromatic, non-aromatic, organically-grown and inorganically-grown rice genotypes. The validation was conducted in San Nicolas, Ilocos Norte during the 2016 dry season (DS) and wet season (WS). The setup was established using the three varieties (Burdagol-Laguna Type, Gal-ong, PSB Rc82) subjected to inorganic (LCC-based 1) and organic (chicken manure) fertilizer treatments. Experiments were conducted to determine the effects of harvesting time, frequency of stirring during sundrying, and type of storage on the yield and grain quality of aromatic and organic rice.

Activities:

- The effects of nitrogen levels on the grain quality parameters, health promoting phytochemicals, and yields of three different rice genotypes grown under the PalayCheck System of integrated crop management for transplanted irrigated lowland rice were determined during 2016 dry season (DS), for its second year of implementation in PhilRice Los Baños. Aromatic variety Burdagol-Laguna Type, a pigmented rice variety (Gal-ong) and a non-aromatic PSB Rc82 were tested in response to inorganic and organic fertilizer treatments.

- The experiment was replicated three times and the treatments were laid out in the field following a Split Plot Design. Nutrient treatments (zero fertilizer, N-omission plot, P-omission plot, K-omission plot, LCC-based N fertilizer level 1, LCC-based N fertilizer level 2, Organic fertilizer 1, Organic fertilizer 2, and Organic fertilizer 3) were the main plot. Variety (PSB Rc82, Burdagol-Laguna Type, and Gal-ong) was the sub-plot. Each plot size was 4m x 5m (20 m^2).

- The third mineralization trial, a pot experiment to determine the nutrient release pattern of organic materials was also conducted from June to September 2015 at PhilRice Los Baños.

- For the site in San Nicolas, Ilocos Norte, in addition to the usual Palaycheck System Key Check 1 (seed quality) to Key Check 7 (pest management), the recently-improved Key Check 8 (harvest management) and the proposed Key Check 9 (post-harvest management) was initially validated for aromatic, non-aromatic, organically-grown and inorganically-grown rice genotypes.

- The 2016 DS set-up was established using the three varieties (Burdagol-Laguna Type, Gal-ong, PSB Rc82) subjected to inorganic (LCC-based 1) and organic (chicken manure) fertilizer treatments. Experiments were conducted to determine the effects of fertilizer treatments, harvesting time, and frequency of stirring during sundrying on the yield and grain quality.

- Harvesting, drying, and storage experiments were established during DS and WS 2016 in San Nicolas, Ilocos Norte to develop and/or verify post-harvest management for aromatic and organic rice. Effects of harvesting time (25, 30, and 35 days after flowering [DAF]), frequency of stirring during sundrying (stirring every 0.5, 1, 2, 4 hours) and type of storage (sack, un-insulated storage bin, insulated storage bin) on the yield and grain quality of aromatic and organic rice were investigated.

Results:

2016 Dry Season, PhilRice Los Baños Site

- The partial yield data of the 2016 dry season rice crop conducted from January to May, 2016 are presented in Table 3. PSB Rc82 produced the highest grain yield (14% MC) at 5.07t/ha-1 but was not significantly different from Burdagol at 4.72t/ha while Gal-ong produced the lowest grain yield at 1.82t/ha. The straw yield did not differ significantly among varieties. The higher grain yield of PSB Rc82 and Burdagol compared to Gal-ong may be attributed to their higher tiller count.

- Across varieties, significantly higher grain yields were obtained from Omission Plot (-P), Omission Plot (-K), LCC-based 1 and 2, and chicken manure compared to other treatments. Lower yields obtained from Omission Plot (-N) and rice straw were not significantly different from the control (no fertilizer applied), suggesting that N was the limiting nutrient and using rice straw alone as fertilizer did not improve the yield.

- In terms of the influence of fertilizer management on grain yields of individual variety, Table 4 shows the same trend with PSB Rc82 and Burdagol wherein Omission Plot (-N), rice straw and the control gave significantly lower grain yields compared to the other fertilizer treatments. With Gal-ong, no significant difference was observed among all fertilizer treatments.

Mineralization Study

The third mineralization trial was actually conducted from June–September 2015 but most of the laboratory analytical data became available only during the first semester of 2016.

Initial Total Organic Carbon, Total Nitrogen and C:N Ratio. Table 5 shows the initial total organic carbon (OC) and total nitrogen (N) of the soil and organic materials used in the study.

- Mungbean stalks (37.2%) and rice straw (35.8%) contained the highest total OC while chicken manure (17.6%) and vermicast (11.4%) had lower total OC.

- Chicken manure contained the highest total N at 4.11% followed by mungbean stalks, vermicast and rice straw at 1.98%, 1.07% and 0.65%, respectively.

- Since rice straw had the highest OC and lowest N, it had the highest C:N ratio of 55.

- Mungbean stalks had a C:N ratio of 19 followed by vermicast with 11 and lastly, chicken manure with 4.

Periodic Changes in Total Organic Carbon. Table 6 and Figure 13 show the changes in total organic carbon content of the organic materials during mineralization test.

- The total OC of organic materials except vermicast decreased from day 0 until 89th day of incorporation. Vermicast had a slight increase in OC which almost stabilized until the 89th day.

- Mungbean stalks reached its highest OC content after 40 days of incorporation but dropped by about 123% at 64th day.

- Chicken manure had a gradual decrease in OC content starting at 6th day after incorporation until 89th days after incorporation.

Mineralization of Nitrogen. Table 7 and Figure 14 show the mineralization rate of nitrogen from different organic materials.

- For rice straw, total N tends to increase with time which might indicate N immobilization by microorganisms. This in turn renders N to be unavailable for plant uptake.

- The same trend is observed for mungbean stalks wherein N content increased by 39% at 26 days of soil incorporation and carried over up to 89th day after soil incorporation. Thus, N in green manures is mostly stored in the soil which can become available upon death of microorganisms.

- Nitrogen in vermicast tends to be immobilized up to 40 days after incorporation but it was subsequently mineralized which was observed in the decreased N content at 64 and 89 days after incorporation.

- Chicken manure had the fastest mineralization rate which was expressed as early as 6 days after incorporation into the soil wherein it released as much as 73% of its initial total N. Thus, it is advised that dried chicken manure can be applied at least 6 days before planting so that plants will be able to maximize from the N release.

Periodic Changes in C:N Ratio. The C:N ratio of rice straw and mungbean stalks decreased while vermicast and chicken manure increased at 89 days after incorporation (Table 8, Figure 15) compared to their initial C:N ratios.

- If C:N ratio will be used as index of decomposition, it can be said that rice straw was considered to be somewhat but not fully decomposed at 89 days after incorporation. Mungbean stalks were fully decomposed at 64 days after incorporation.

- Chicken manure started to increase its C:N ratio at 6th day of incorporation but decreased gradually from 26th day onwards until the 89th day of incorporation. The C:N ratios however remained higher than the initial (day 0) C:N ratio.

- Vermicast had a gradual increase in C:N ratio due to increasing carbon and decreasing nitrogen content with time.

Changes in Total Soil Organic Carbon, Total Soil Nitrogen and C:N Ratio During Mineralization Test

- Soil organic carbon generally decreased for all of the treatments at about the same level of 45% after 89 days of incorporation (Table 9), Figure 16).

- Generally, N content of soils treated with different organic materials increased from initial N content suggesting that N mineralization had occurred (Table 10, Figure 17).

- Comparing the different organic materials, vermicast had significantly the highest N contribution at 53% followed by rice straw (34%), chicken manure (26%), and mungbean stalks (10%).

- Generally, the C:N ratio of the soil decreased with time with vermicast having the highest reduction at 73% followed by rice straw (63%), chicken manure (58%) and mungbean stalks (50%) (Table 11, Figure 18).

2016 Dry Season, San Nicolas, Ilocos Norte

- A field setup was established in San Nicolas, Ilocos Norte in 2016 dry season (DS) to develop and/or verify pre-harvest and post-harvest management for aromatic and organic rice.

- From the field setup, three experiments were conducted with the following details:
  Nutrient management - Organic (Chicken manure) and inorganic (LCC-based 1)
  Harvesting time - 25, 30, and 35 days after flowering (DAF)
  Drying (frequency of stirring) – every 30 minutes, 1, 2, and 4 hours

- Nutrient management was assigned as the main plot: organic and inorganic (LCC- based) while varieties in the subplot (PSB Rc82, Burdagol (Laguna-type) and Gal-Ong (Trad var).

- The yield was significantly affected by the variety. Burdagol Laguna-type produced the highest yield (6.24t/ha) while Gal-ong was the lowest (1.72t/ha) as shown in Table 12. The interaction of the variety and fertilizer treatments significantly affected the yield. Only the Gal-ong rice had higher yield when applied with chicken manure than when applied with LCC-based 1.

- The yield of the different varieties both for inorganic and organic rice was not significantly affected by harvesting time during the 2016 DS (Tables 13 and 14). However, it was significantly affected during WS. Yield of the varieties during WS at inorganic setup were higher when harvested at 25 to 30 DAF. However, it significantly reduced when harvested at 35 DAF. For the organic setup, yield was higher when harvested at 25 DAF and significantly reduced when harvested beyond (Tables 3 to 6).

- For the drying experiment, every 30 minutes stirring gave the shortest time of drying the paddy rice and lowest variations in moisture contents compared to the other treatments (Figures 13 through16).

Table 3. Effect of fertilizer management and varieties on grain yield and other yield parameters, PhilRice Los Baños (2016 DS).

Parameters	Control	Plot (-N) 0-28-28	Plot (-P) 98-0-28	Plot (-K) 98-28-0	Based 1 98-28-28	Based 2 134-28-28	Straw 4 t ha^{-1}	manure 3 t ha-1
Grain Yield, 14% MC (t ha^{-1})	3.10 b	3.09 b	4.33 a	4.41 a	4.22 a	4.23 a	3.38 b	4.18 a
Straw Yield, ODW (t ha^{-1})	3.57 c	4.01 bc	5.57 a	5.82 a	5.43 a	5.72 a	4.08 bc	4.89 ab
Yield Components								
Initial Plant height (cm)	76.0 d	77.5 d	88.8 b	90.0 ab	88.1 bc	94.1 a	75.8 d	84.0 c
Plant height at harvest (cm)	97.8 cd	96.6 d	112.3 a	108.3 ab	109.9 ab	112.8 a	97.2 d	103.8 bc
Initial Tiller Count (n)	9 ab	8 b	10 ab	10 ab	10 ab	11 a	8 b	10 ab
Tiller count at harvest (n)	10 c	10 c	12 ab	12 ab	12 ab	14 a	10 bc	11 bc
Productive tiller count (n)	9 b	9 b	11 ab	10 b	11 ab	13 a	9 b	10 b

In a row for each parameter, means followed by the same letter are not significantly different at 5% level of sig

Table 4. Grain yield of three varieties as influenced by fertilizer management, PhilRice Los Baños (2016 DS).

Fertilizer Management	Fertilizer Rate N-P-K (kg ha^{-1})	Grain Yield (%14MC), t ha^{-1} Burdagol	Gal-ong	PSB Rc82
Control	0-0-0	3.53 c	1.59 a	4.17 b
Omission Plot (-N)	0-28-28	3.84 c	1.45 a	3.97 b
Omission Plot (-P)	98-0-28	5.42 a	1.86 a	5.70 a
Omission Plot (-K)	98-28-0	5.49 a	1.79 a	5.96 a
LCC Based 1	98-28-28	5.12 ab	1.93 a	5.63 a
LCC Based 2	134-28-28	5.18 ab	1.59 a	5.93 a
Rice Straw	4 t ha^{-1}	4.03 bc	1.93 a	4.17 b
Chicken Manure	3 t ha^{-1}	5.12 ab	2.41 a	5.02 ab

In a column, means followed by the same letter are not significantly different at 5% level of significance (DMRT).

Table 5. Initial total organic carbon and total nitrogen of soil and organic materials used in the mineralization study.

Organic Materials	Total Organic Carbon, OC (%)	Total Nitrogen, N (%)	C:N ratio
Soil	2.80	0.17	16
Rice straw	35.76	0.65	55
Vermicast	11.42	1.07	11
Mungbean stalks	37.19	1.98	19
Chicken manure	17.56	4.11	4

Table 6. Periodic changes in total organic carbon (%).

Organic Materials	Days after incorporation (n) 0	6th	26th	40th	64th	89th
Rice Straw	35.76	32.98	32.79	31.14	35.71	22.20
Vermicast	11.42	14.90	14.60	14.62	13.88	15.08
Mungbean Stalks	37.19	58.12	59.76	61.85	27.77	29.99
Chicken Manure	17.56	17.52	12.72	9.94	9.14	9.08

Table 7. Mineralization rate of total N (%).

Organic materials	Day after incorporation (n) 0	6th	26th	40th	64th	89th
Rice Straw	0.65	0.57	0.74	0.96	0.95	1.45
Vermicast	1.07	1.19	1.23	1.25	1.02	0.99
Mungbean Stalks	1.98	2.28	3.23	3.08	3.22	3.23
Chicken Manure	4.11	1.10	1.01	0.90	1.13	0.90

Table 8. Periodic changes in C:N ratio of organic materials during mineralization test.

Organic Materials	Day after incorporation (n) 0	6th	26th	40th	64th	89th
Rice Straw	55	58	44	32	37	16
Vermicast	11	12	12	12	14	15
Mungbean Stalks	19	26	19	21	9	9
Chicken Manure	4	16	13	11	8	10

Table 9. Comparison of total soil organic carbon (%) and percent reduction before and after mineralization test of different organic materials.

Organic Materials	Initial Soil Organic C	Total Soil Organic C after mineralization test	% Decrease
Rice straw	2.80	1.54	82
Vermicast	2.80	1.55	81
Mungbean stalks	2.80	1.53	83
Chicken manure	2.80	1.55	81

Table 10. Comparison of total soil nitrogen (%) and percent increase before and after mineralization test .

Organic materials	Initial Total Soil N	Total Soil N after mineralization test	% Increase
Rice straw	0.17	0.26	34
Vermicast	0.17	0.36	53
Mungbean stalks	0.17	0.19	10
Chicken manure	0.17	0.23	26

Table 11. Comparison of soil C:N ratio and percent decrease before and after mineralization test.

Organic materials	Initial Total Soil N	Total Soil N after mineralization test	% Increase
Rice straw	0.17	0.26	34
Vermicast	0.17	0.36	53
Mungbean stalks	0.17	0.19	10
Chicken manure	0.17	0.23	26

Table 12. Yield of the varieties as influenced by fertilizer treatments.

Fertilizer Treatment	Yield (t/ha)			MEAN
	Burdagol Laguna-Type	Gal-ong	PSB Rc82	
LCC-based 1	6.99 a	1.16 b	5.21 a	4.45 a
Chicken manure	5.49 b	2.29 a	3.47 b	3.75 a
Mean	6.24 a	1.72 c	4.34 b	
Significance				
Nutrient Management (A)	ns			
Variety (B)	***			
A x B	***			

*ns-not significant; *** - significant at 0.1% level of significance*
Means followed by common letter are not significantly different from each other at 5% level of using LSD

Table 13. Yield of the varieties for norganic ice as affected by harvesting time.

Harvesting Time (days after flowering or DAF)	Yield (t/ha)			
	Burdagol Laguna-Type	Gal-ong	PSB Rc82	Mean
25	6.50	1.65	5.42	4.52 a
30	6.99	1.16	5.20	4.45 a
35	6.82	0.90	4.18	3.97 a
Mean	6.77 a	1.24 c	4.94 b	
Significance				
Harvesting time (A)	ns			
Variety (B)	***			
A x B	ns			

*ns-not significant; *** - significant at 0.1% level of significance*
Means followed by common letter are not significantly different from each other at 5% level of using LSD

Table 14. Yield of the varieties for organic rice as affected by harvesting time.

Harvesting Time (days after flowering or DAF)	Yield (t/ha)			
	Burdagol Laguna-Type	Gal-ong	PSB Rc82	Mean
25	6.05	1.94	3.82	3.94 a
30	5.49	2.29	3.47	3.75 a
35	5.77	_	3.31	4.54 a
Mean	5.77 a	2.12 c	3.53 b	
Significance				
Harvesting time (A)	ns			
Variety (B)	***			
A x B	ns			

*ns-not significant; *** - significant at 0.1% level of significance*
Means followed by common letter are not significantly different from each other at 5% level of using LSD

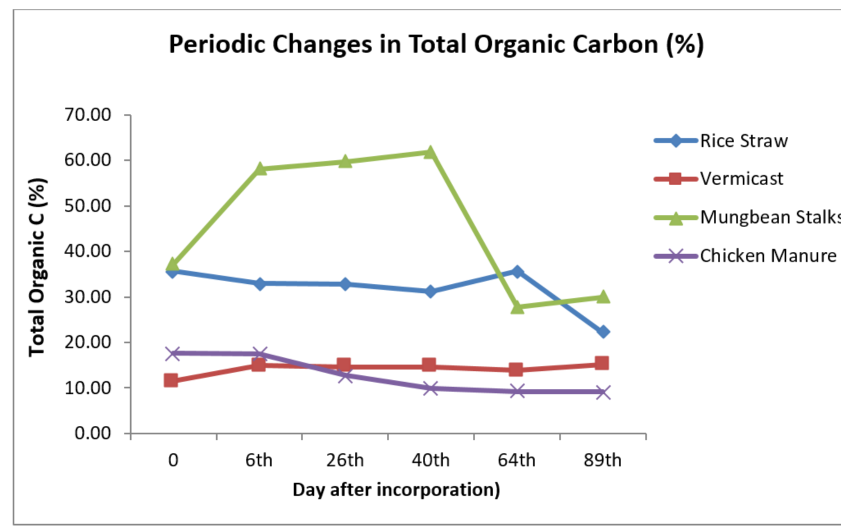

Figure 14. Periodic changes in total organic carbon.

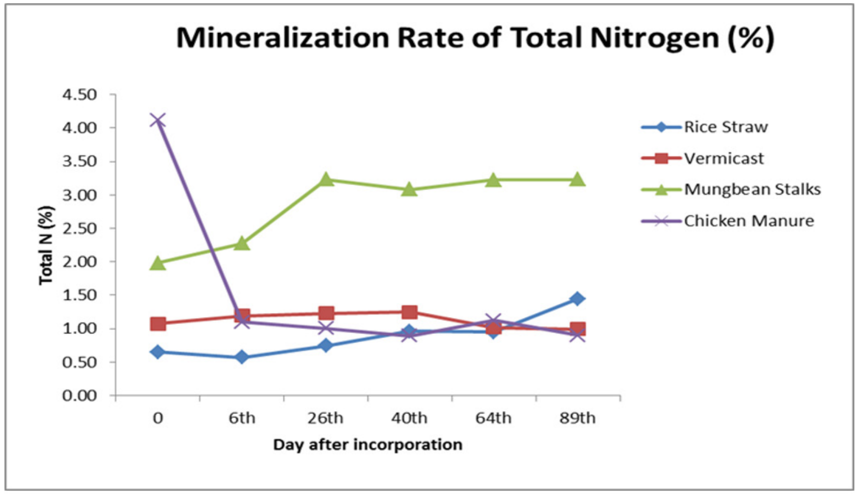

Figure 15. Periodic changes in total nitrogen.

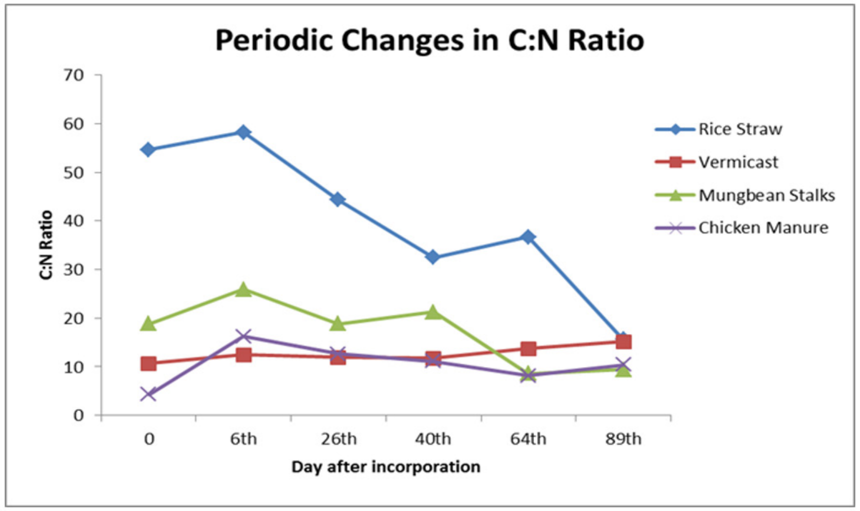

Figure 16. Periodic changes in C:N ratio.

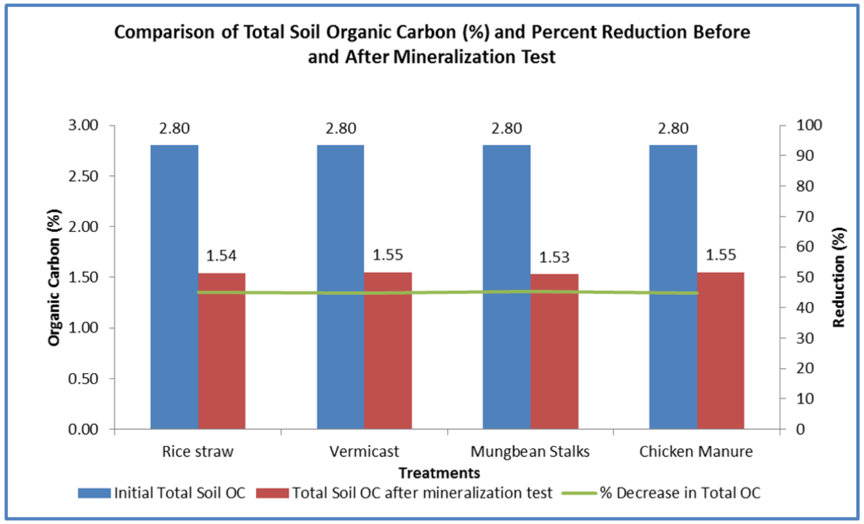

Figure 17. Comparison of total soil organic C before and after mineralization test.

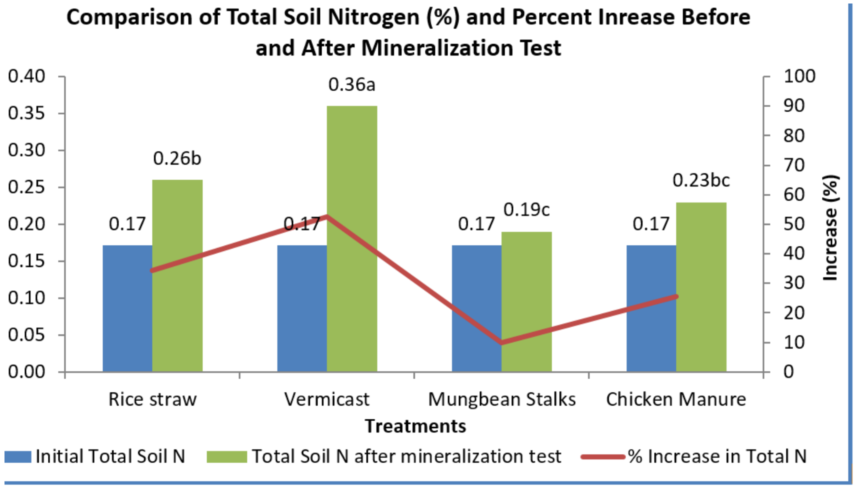

Figure 18. Comparison of total soil organic N before and after mineralization test.

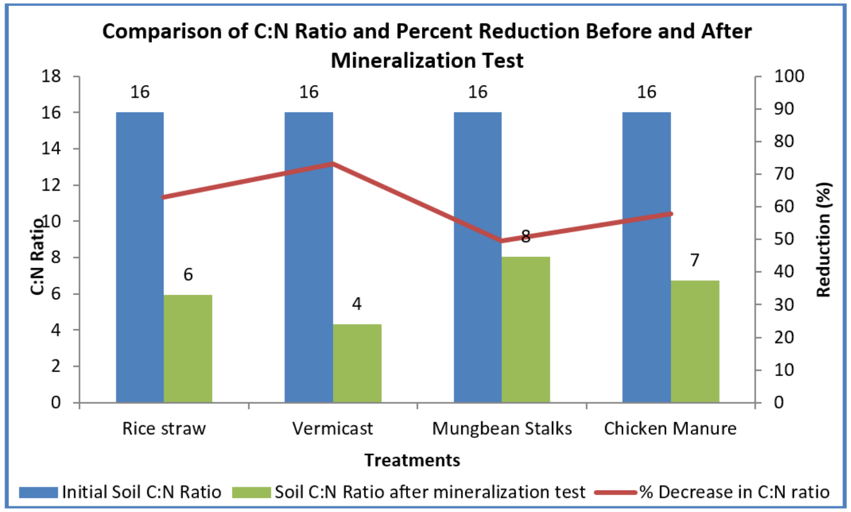

Figure 19. Comparison of soil C:N ratio before and after mineralization test.

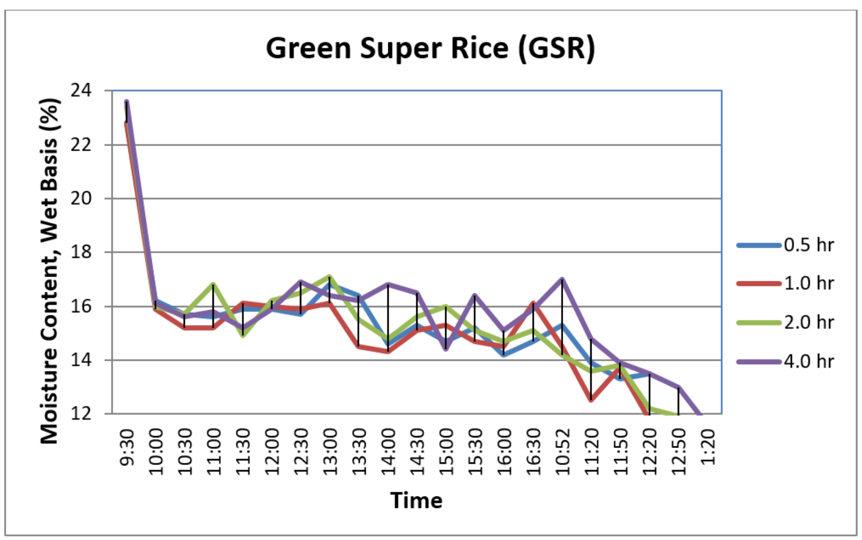

Figure 20. Moisture reduction (%) in Grain Super Rice (GSR) as affected by the frequency of stirring. Ambient temperature (33.3 °C), relative humidity (50.6%), and grain temperature (36.4 °C).

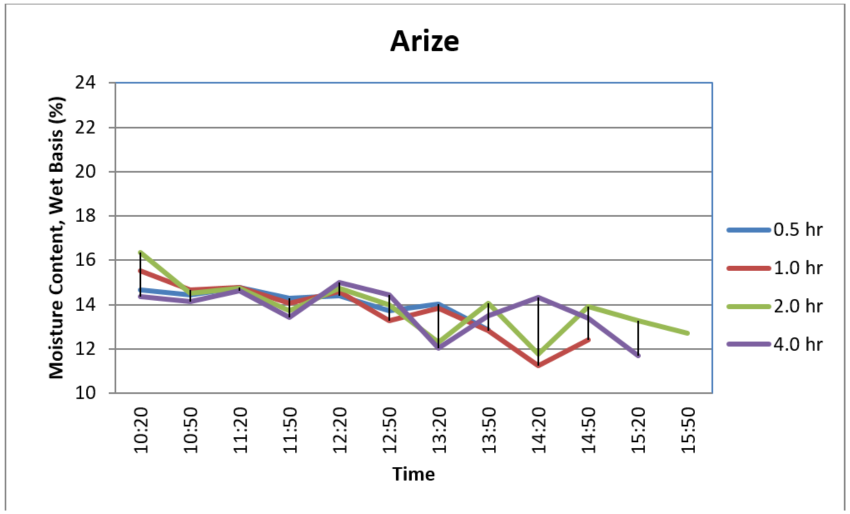

Figure 21. Moisture reduction (%) in Arize as affected by the frequency of stirring. Ambient temperature (31.8 °C), relative humidity (55.8%), and grain temperature (36.1 °C).

Establishing isotopic fingerprints in popular and traditional rice varieties
NC Ramos, PCC Pabroa, and MV Romero

Rice is the basic food for nearly half the people on earth, most of them in Asia. The expansion of global trade has promoted the international trade of rice. With that, agricultural products are increasingly labeled with their geographical origin in many countries for branding strategy purposes and help consumers in their selection of foodstuffs. For rice, this information is important to consumers and stockholders.

A simple analytical method that can identify milled rice varieties is required to resolve these rice aunthenticity problems. Isotopic composition of one or more elements present in the samples can be often be used for identification purposes, as several factors can lead to measurable differences depending on “the environment”. Isotopic analysis is an effective tool since isotopic ratio in a crop inherits the geological character of a production area. Additional technique is the use of chemometrics to further identify distinction among the samples.

Activities:

- A total of 239 rice samples of NSIC Rc222, PSB Rc18, PSB Rc10, and NSIC Rc160 were collected from 11 regions in the Philippines. The rice samples were dehulled, polished and washed thrice. The samples were dried and ground using mortar and pestle.

- All rice samples were analyzed for multi-element analysis such as Cu, Mn, Zn, Fe, Si, Ti, Sr, Zr, Rb, V, and S using the Microwave Plasma Atomic Emission Spectroscopy (MP-AES) at National Institute of Geological Sciences at University of the Philippines Diliman.

- A total of 136 rice samples were analyzed for carbon-13 analysis using IRMS at Philippine Nuclear Research Institute. Analysis for the remaining 100 rice samples is on-going.

- About 50 traditional rice varieties collected from various regions in the country were selected for isotopic analysis. The samples will be submitted to the Analytical Services Laboratory at the International Rice Research Institute.

Results:

- The isotopic analysis, specifically C13, of the 139 rice samples collected from Regions 1-8 ranges from -27.5% to -29.5%. The geographical origin of the rice samples will be determined using chemometrics. Based on the data, possible discrimination using principal component analysis (PCA).

- The multi element analyses of the 239 rice samples were carried to determine possible discrimination of the samples when PCA will be applied. Based on Table 15.

Table 15. Concentration of the metals in milled rice determined by Microwave Plasma Atomic Emission Spectroscopy (MP-AES).

Location	*n*	*Cu*	*Mn*	*Zn*	*Fe*	*Si*	*Ti*	*Sr*	*Zr*	*Rb*	*V*	*S*
		ppm	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*
Region 1	19	3.2 ± 0.2^{a}	9.0 ± 1.5^{d}	8.3 ± 1.9^{e}	0.32 ± 0.04^{e}	0.38 ± 0.03^{b}	0.025 ± 0.003^{b}	0.011^{a}	0.002 ± 0.001^{a}	nd	0.001^{a}	0.006
Region 2	20	2.9 ± 0.2^{c}	11.2 ± 0.7^{c}	14.0 ± 0.2^{a}	0.25 ± 0.04^{f}	0.47^{a}	0.018^{f}	0.010 ± 0.002^{a}	0.002^{a}	0.001^{a}	0.001^{a}	0.012
Region 3	20	2.1 ± 0.4^{f}	8.3 ± 4.1^{e}	10.3 ± 0.6^{d}	0.48^{a}	0.33 ± 0.01^{d}	0.025 ± 0.001^{b}	0.005^{d}	0.002^{a}	0.002^{a}	0.002^{a}	0.007
Region 4B	18	1.8 ± 0.5^{g}	7.0 ± 1.5^{f}	9.1 ± 1.2^{e}	0.46 ± 0.01^{b}	0.33^{d}	0.025 ± 0.001^{b}	0.005^{d}	0.002^{a}	0.001^{a}	0.001^{a}	0.005
Region 5	21	2.5 ± 0.3^{d}	9.1 ± 2.0^{d}	12.3 ± 0.4^{c}	0.44^{c}	0.37 ± 0.05^{b}	0.032 ± 0.005^{a}	0.005^{d}	0.003 ± 0.001^{b}	0.001^{a}	0.002^{a}	0.007
Region 6	23	2.7 ± 0.5^{c}	12.2 ± 4.1^{c}	11.8 ± 0.4^{c}	0.43 ± 0.08^{c}	0.37 ± 0.06^{b}	0.031 ± 0.005^{a}	0.002 ± 0.001^{e}	0.005 ± 0.001^{c}	0.001^{a}	0.001^{a}	0.018
Region 7	24	2.4 ± 0.3^{d}	14.3 ± 4.8^{a}	13.2 ± 3.0^{b}	0.43 ± 0.06^{c}	0.34 ± 0.03^{c}	0.021 ± 0.005^{c}	0.004 ± 0.004^{d}	0.002 ± 0.001^{a}	nd	0.001^{a}	0.012
Region 8	25	2.2 ± 0.2^{e}	11.1 ± 4.5^{c}	8.5 ± 3.2^{e}	0.34 ± 0.04^{e}	0.33 ± 0.04^{d}	0.022 ± 0.002^{c}	0.010^{a}	0.002^{a}	nd	0.002^{a}	0.012
Region 10	22	3.2 ± 0.2^{a}	12.1 ± 4.6^{c}	7.5 ± 1.2^{f}	0.37 ± 0.05^{d}	0.30 ± 0.03^{e}	0.019 ± 0.001^{e}	0.009 ± 0.001^{b}	0.002^{a}	nd	0.001^{a}	0.008
Region 11	25	2.9 ± 0.2^{b}	11.1 ± 4.9^{c}	8.2 ± 0.9^{e}	0.33 ± 0.07^{e}	0.35 ± 0.08^{c}	0.022 ± 0.003^{c}	0.008 ± 0.001^{b}	0.002^{a}	nd	0.002^{a}	0.013
Region 13	21	2.5 ± 0.4^{d}	13.4 ± 2.4^{b}	12.1 ± 1.2^{c}	0.44 ± 0.05^{c}	0.31 ± 0.12^{f}	0.020^{e}	0.007 ± 0.006^{c}	0.003^{b}	nd	0.001^{a}	0.010

Note: nd – not detected; below LOD; Cd and Pb were not detected in all samples

II. High-Value Products from the Rice Grain and Other Parts of the Rice Plant

Project Leader: APP Tuaño

Rice has been cultivated in the country mainly as source of food. Its potential as source of industrially important compounds (biomolecules and secondary metabolites) has not yet been fully investigated in the country and using local rice cultivars, despite the large land area dedicated to rice farming. This is due to the main interest on the rice grain, particularly as milled rice, which consists of around 90 to 92% starch serving as the primary source of dietary caloric requirements of Filipinos. This project aims to explore the potential of the rice grain, rice plant parts and rice cell and organ cultures as sources of biomolecules such as proteins, bioactive peptides, carbohydrate-based prebiotics, and beneficial secondary metabolites like lignans, flavonoids, terpenoids, antioxidants, anthocyanins, phytic acid and other bioactive components having nutritional, biomedical/health-related and industrial applications. It includes survey, screening and characterization of rice cultivars (modern and traditional), their plant parts and cell cultures derived from them in order to determine best sources of the compounds of interest. Processes, methodologies and technologies necessary for the development of production systems/product prototypes of marketable high-value products from abovementioned sources are expected to be delivered at the end of the project.

Extraction and encapsulation of antioxidants and proteins from rice bran for functional food and biomedical applications

RMBulatao, JPASamin, RPTubera, RVManaois, AVMorales, BSPeralta, and HMCorpuz

Rice bran is a low-valued by-product of rice processing yet is a good source of useful ingredients and products. It is a good source of edible and healthful products since it contains about 11-17% protein, 12-18% fats, 6-15% fiber, and 18% carbohydrates. It also contains substantial amount of essential vitamins, minerals, and natural phytochemicals, which are known to have therapeutic and health-enhancing properties. Pigmented rice bran is nutritionally superior compared with ordinary white rice as it contains higher amount of nutrients and phytochemicals. Specifically, it contains more of phenolic compounds like anthocyanins, which have anticancer, hypoglycaemic, and anti-inflammatory health benefits. In this regard, utilization of nutritious rice bran as source of natural antioxidants and proteins could be one of the sustainable strategies in order to maximize the use of essential nutrients and phytochemicals that are usually removed during the milling process. This cheap agricultural by-product when properly utilized as food ingredients might be a good response to the escalating chronic disease incidence facing our country today. Thus, this study was

intended to extract and characterize antioxidants and proteins from rice bran for functional food, pharmaceutical and biomedical applications.

Activities:

- Extraction of anthocyanins from rice bran was optimized using Response Surface Methodology (RSM).
- Crude anthocyanin extracts (CAEs) produced using optimized and conventional methods were compared in terms of total anthocyanin, phenolic, and flavonoid contents, and antioxidant activities (DPPH and FRAP assays).
- Stability of CAEs in biologically relevant buffers was determined for 48 hr. The treatments employed were as follows: T0-CAEs + pH 1.0 buffer at 25°C; T1-CAEs + pH 7.4 buffer at 25°C; T2-CAEs + pH 7.4 buffer + 10% Newborn calf serum at 25°C; T3-CAEs + pH 1.0 buffer at 37°C; T4-CAEs + pH 7.4 buffer + 10% Newborn calf serum at 37°C.
- Effective concentrations at 50 (EC50) of pigmented rice bran extracts were determined.
  Anticlastogenic property of black and red rice extracts was evaluated using white mice at the Pampanga State Agricultural University, Magalang, Pampanga (Figure2).
- Cell toxicity of pigmented rice bran extracts was evaluated against normal human blood lymphocytes using trypan blue exclusion assay at the Natural Sciences Research Institute, University of the Philippines-Diliman, Quezon City.

Results:

- Extraction of anthocyanin from Ominio bran was optimized using the Response Surface Methodology (RSM). Two methods were employed for the screening and optimization of independent variables, namely, the two level full factorial and Box-Behnken design. Ethanol and HCl concentrations and shaking time were identified as independent variables. All independent variables were found to be significant, thus exerted a positive impact during extraction. Significant interactions were also observed in the model particularly between solvent and HCl concentrations, and solvent concentration and shaking time. Furthermore, the established optimum conditions for the efficient extraction of anthocyanin using RSM were found to be 60% of ethanol, 0.2% of HCl, and 3.5hr of extraction time. The predicted response of the model for the total anthocyanin content under these conditions was

90.25mg/g with a relative error of 0.05% (Experimental value = 90.20mg/g). The optimized method was found to be more efficient, less laborious, and cost-effective way to extract anthocyanin from black rice bran.

- Optimized method produced an extract with higher total anthocyanin, phenolic, and flavonoid contents, DPPH radical scavenging activity, and Ferric reducing antioxidant power compared with the conventional method (Table 16).

- CAEs under acidic condition did not undergo substantial degradation regardless of temperature (Figure 22). Whereas, CAEs under slightly basic solution undergo rapid degradation. Since T2 and T4 underwent quick degradation, their half-life were calculated and found to be 32.5hr and 28.9hr, respectively.

- Black rice (Ominio) bran extract significantly reduced the micronucleated polychromatic erythrocytes (MPCEs) in bone marrow cells of tetracycline-induced cancer white mice by 42 to 49% while red rice (Chor-chor-os) bran extract decreased by 33 to 37%. This implies that the black and red rice bran extracts can be considered as anticlastogenic to the bone marrow cells of the clastogen-induced white mice. This might be due to the phytochemicals present in the bran extracts that can counteract the chromosome-breaking effect of the tetracycline.

- EC50 estimates the concentration of pigmented rice bran extracts that causes 50% reduction in the DPPH concentration. It is inversely correlated with the antioxidant activity of the samples. Bran extracts of Ominio (11.5mg/L) and Gomiki (21.2mg/L) had the lowest EC50, indicating that these samples require low concentration of extracts to reduce the concentration of free radicals by 50%.

- Black and red rice bran extracts at concentrations ranging from 100 to 1000 ppm showed no toxic effect on normal human blood lymphocytes. This implies that pigmented rice bran extracts is safe to consume by humans at those concentrations, therefore, can be used as ingredient in the formulation of different functional food and pharmaceutical products.

Table 16. Comparison of crude anthocyanin extracts (CAEs) obtained from optimized and conventional methods of extraction.

Phytochemical Analyses	Extraction Method	
	Conventional Mean±SD (mg/g)	Optimized Mean±SD (mg/g)
Total Anthocyanin Content	22.43±0.26	90.20±0.65
Total Phenolic Content	30.66±1.15	50.07±1.54
Total Flavonoid Content	66.22±0.61	92.18±0.60
DPPH Radical Scavenging Activity	33.67±0.28	75.82±0.10
Ferric Reducing Antioxidant Power	70.90±2.25	120.23±0.77

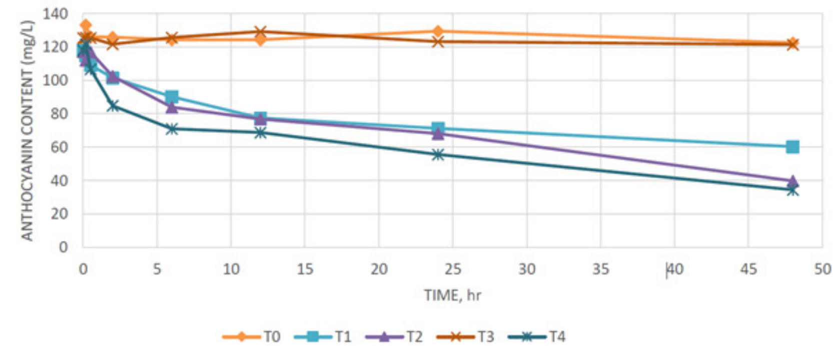

Figure 22. 48-hr stability of anthocyanin extract in biologically relevant buffers.

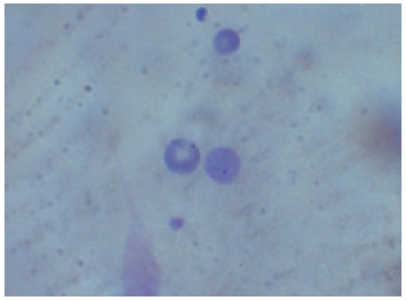

Figure 23a. Arrow pointing the micronucleated polychromatic erythrocyte.

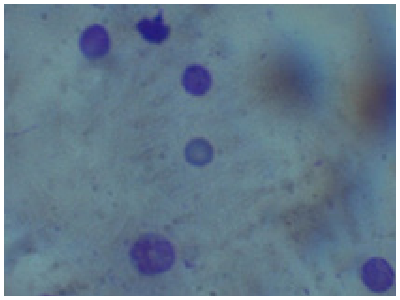

Figure 23b. Arrow pointing the normal micronucleated polychromatic erythrocyte.

Prebiotics from rice: Dietary Fiber, resistant starch and xylooligosaccharides
RVManaois and JEIZapater

Prebiotics are food components not digested and absorbed in the small intestines, but instead are fermented in the large intestines and are metabolized by resident beneficial microorganisms, resulting in improved gut health. Their resistance to digestion results in hypoglycemic effects, which in turn helps combat risks of diseases associated with high blood glucose levels such as diabetes and obesity. Different parts of the rice grain could be explored as potential sources of various prebiotics, such as resistant starch, dietary fiber, and xylooligosaccharides. This study was conducted to evaluate these healthful substances from rice and optimize processes to further enhance their content for potential functional food product development. For this year, the different physicochemical properties, cooking parameters, and viscosity profiles of the different rice varieties were determined to screen for varieties with higher potential for RS formation and DF isolation.

Activities:

- Ten non-pigmented modern rice varieties (NSIC Rc238, NSIC Rc118, NSIC Rc242, NSIC Rc298, NSIC Rc222, NSIC Rc160, NSIC Rc152, PSB Rc10, PSB Rc14 and PSB Rc82) grown in Maligaya, Science City of Muñoz, Nueva Ecija during the 2015 WS and one traditional black rice (Inipot Ibon) cultivated in 2016 DS in Bontoc, Mt. Province were procured as test samples.. The samples were processed and determined for their physicochemical properties, namely amylose content (AC) using the modified iodine staining method of Juliano et al. (2012), gelatinization temperature (GT) using alkali spreading value (ASV) test, and crude protein (CP) content using the standard Kjeldahl method (AOAC, 2000).

- Ten rice samples were subjected to parboiling using a lab optimized method of Corpuz et al. (2013). Parboiled grains were cooked and the Instron hardness compared with non-parboiled samples using t-test at $p<0.05$.

- The different properties of the 10 modern rice samples were evaluated, along with six traditional pigmented varieties, which were previously assayed. This was done to select for samples for pasting profile determination by Rapid Visco Analyzer. The selected samples comprised of one black, four red and five white rice varieties.

- A total of 21 rice samples (3 black, 10 white and 8 red) were collected for crude fiber (CF) analysis. In addition to the abovementioned 10 modern rice varieties, 11 traditional (Balikwadang, Gomiki, Imbuucan, Ingopon, Kamanga, Minaangan, Red Blondie, Kotinaw, Galo, Ominio, and Chong-ak) were processed and their brans were subjected to crude fiber analysis using the standard ISO 6865:2000 method.

Results:

- Table 17 summarizes the physicochemical properties of 10 modern and six traditional pigmented rice varieties. The samples had apparent amylose content (AC) ranging from 0.54 to 28.7%. Two varieties were classified as waxy, two low, five intermediate, and seven high amylose types. The ASV ranged from 2.33 to 7.0, which were classified as low to high GT. Crude protein ranged from 6.1 to 9.3%, NSIC Rc242 having the highest CP while NSIC Rc160 having the lowest.

- Eleven of the samples were subjected to parboiling treatment and the Instron hardness values were compared with those of their non-parboiled counterparts. The Instron hardness values of parboiled traditional samples were generally higher than those of their non-parboiled counterparts (Table 18). For the modern varieties, parboiling resulted in more tender cooked rice.

- Table 19 shows the pasting profiles of 10 selected rice samples. The highest peak, trough, final, and setback viscosities were recorded for Minaangan (intermediate AC), NSIC Rc222, and PSB Rc10 (both high AC). The pasting temperatures ranged from 71.25 to 78.30^{o}C. Minaangan had the highest retrogradation potential (2821.5 cP), followed by PSB Rc10 (2520.5 cP) and NSIC Rc222 (2261.0 cP).

- The crude fiber content of 21 rice bran samples are presented in Table 20. The crude fiber content ranged from 7.62 to 11.61%. The bran samples with the highest CF (>10%) were: Red Blondie, NSIC Rc242, NSIC Rc152, NSIC Rc298, PSB Rc14, and Minaangan.

Table 17. Physicochemical properties of rice samples (n=3).

Rice Variety	Color	CP (%)	AC		GT	
			Value (%)	Class[2]	ASV	Class[3]
Balikwadang	Red	7.2	0.5	Wx	2.6	H/HI
Imbuucan	Red	8.7[1]	22.7	H	5.0	I
Ingopon	Black	7.1	0.6	Wx	2.8	H/HI
Inipot Ibon	Black	8.8	22.4	H	5.1	H/HI
Gomiki	Red	5.6	24.1	H	6.0	L
Kamanga	Red	7.2	23.6	H	5.0	I
Minaangan	Red	5.8	19.4	I	6.0	L
NSIC Rc152	White	6.9[1]	28.7[1]	H	7.0[1]	L
NSIC Rc118	White	8.5	18.2	I	2.3	H/HI
NSIC Rc160	White	6.1[1]	15.7[1]	L	6.0[1]	L
NSIC Rc222	White	6.5[1]	23.9[1]	H	4.6[1]	I
NSIC Rc238	White	7.0	22.0	H	6.4	L/I/HI
NSIC Rc242	White	9.3[1]	11.5	L	6.1	I/L
NSIC Rc298	White	6.7[1]	19.7	I	2.7	H/HI
PSB Rc10	White	7.6	24.2	H	3.2	HI/I
PSB Rc14	White	7.9	20.0	I	2.5	H/HI/I
PSB Rc82	White	6.3	20.6	I	2.3	H/HI/I

CP, crude protein content; AC, amylose content; ASV, alkali spreading value; GT, gelatinization temperature
[1]Data from the Bandonill et al. (2016) .
[2]High (H), >22.0% AC, Intermediate (I), 17.1-22.0%, Low (L), 10.1-17.0%, Waxy (Wx), 0.00-2.00%.
[3]H (74.5-80ºC), I (70-74ºC), L (<70ºC)

Table 18. Instron hardness of parboiled and non-parboiled rice samples.

Rice Variety	Instron Hardness (kgf/gm^2)[1]	
	Non-parboiled	Parboiled
Balikwadang	0.94 ± 0.05	0.82 ± 0.04
Imbuucan	2.75 ± 0.04*	3.65 ± 0.04*
Inipot Ibon	1.73 ± 0.03*	1.21 ± 0.02*
Ingopon	0.97 ± 0.02	1.02 ± 0.04
Gomiki	1.93 ± 0.04*	3.07 ± 0.04*
Kamanga	2.32 ± 0.01*	3.51 ± 0.05*
Minaangan	2.42 ± 0.01*	3.62 ± 0.06*
NSIC Rc160	1.57 ± 0.10*	0.78 ± 0.02*
NSIC Rc222	2.07 ± 0.02*	1.79 ± 0.06*
NSIC Rc242	1.19 ± 0.08*	0.55 ± 0.00*
PSB Rc14	1.60 ± 0.04*	1.29 ± 0.07*

[1]Means ± SD (n=3). Mean values across a row with * are significantly different (p<0.05).

Table 19. Viscosity profiles of rice samples.

Rice Variety	Peak Viscosity (cP)	Trough Viscosity (cP)	Breakdown Viscosity (cP)	Final Viscosity (cP)	Peak Time (min)
Imbuucan	3118.5 ± 4.9^{bc}	1732.0 ± 14.1^{d}	1386.5 ± 9.2^{ab}	3486.0 ± 4.2^{d}	5.60 ± 0.00^{cde}
Ingopon	2898.5 ± 17.7^{d}	2059.0 ± 11.3^{c}	839.5 ± 6.4^{d}	2455.5 ± 10.6^{f}	5.00 ± 0.10^{f}
Gomiki	2975.0 ± 76.4^{cd}	1591.5 ± 38.9^{de}	1383.5 ± 37.5^{ab}	3353.0 ± 39.6^{d}	5.77 ± 0.05^{bcd}
Kamanga	3084.0 ± 90.5^{bcd}	1704.5 ± 31.8^{d}	1379.5 ± 122.3^{ab}	3492.5 ± 26.2^{d}	5.80 ± 0.00^{bc}
Minaangan	3698.5 ± 34.6^{a}	2553.5 ± 6.4^{a}	1145.0 ± 28.3^{c}	5375.0 ± 36.8^{a}	5.60 ± 0.00^{cde}
NSIC Rc160	3212.5 ± 70.0^{b}	1662.5 ± 34.6^{de}	1550 ± 35.4^{a}	2947.5 ± 50.2^{de}	5.57 ± 0.05^{de}
NSIC Rc222	3575.5 ± 17.7^{a}	2250.0 ± 159.8^{b}	1325.5 ± 142.1^{abc}	4511.0 ± 22.6^{c}	5.50 ± 0.04^{e}
NSIC Rc242	2984.0 ± 8.5^{cd}	1744.0 ± 36.8^{d}	1240.0 ± 28.3^{bc}	2890.5 ± 47.4^{e}	6.10 ± 0.04^{a}
PSB Rc10	3227.0 ± 80.6^{b}	2386.0 ± 58.0^{ab}	841.0 ± 22.6^{d}	4906.5 ± 108.2^{b}	5.90 ± 0.04^{b}
PSB Rc14	2969.5 ± 29.0^{cd}	1493.0 ± 12.7^{e}	1476.5 ± 16.3^{a}	3081.0 ± 0.0^{e}	5.64 ± 0.05^{cde}

Mean values with the same small letter within the same column are not significantly different (p<0.05).

Table 20. Crude fiber of rice bran samples.

Rice Variety	Bran Color	Crude Fiber[1]	Rice Variety	Bran Color	Crude Fiber[1]
Balikwadang	Red	9.65 ± 0.39^{cde}	Kamanga	Red	7.86 ± 0.01^{fg}
Minaangan	Red	10.47 ± 0.13^{abcd}	Kotinaw	Red	9.91 ± 0.20^{bcde}
Imbuucan	Red	8.89 ± 0.57^{ef}			
Ingopon	Black	9.23 ± 0.30^{de}	NSIC Rc222	Brown	9.04 ± 0.33^{e}
NSIC Rc118	Brown	9.51 ± 0.11^{cde}	NSIC Rc152	Brown	11.32 ± 0.65^{a}
NSIC Rc160	Brown	9.52 ± 0.08^{cde}	PSB Rc10	Brown	9.65 ± 0.02^{cde}
NSIC Rc238	Brown	9.84 ± 0.36^{bcde}	Chong-ak	Red	7.57 ± 0.28^{g}
NSIC Rc242	Brown	11.41 ± 0.11^{a}	Gomiki	Rdd	7.62 ± 0.15^{g}
NSIC Rc298	Brown	10.99 ± 0.09^{ab}	Galo	Black	7.71 ± 0.31^{g}
PSB Rc14	Brown	10.56 ± 0.04^{abc}	Ominio	Black	8.89 ± 0.85^{ef}
PSB Rc82	Brown	9.68 ± 0.21^{cde}	Red Blondie	Red	11.61 ± 0.24^{a}

[1]Mean ± SD (n=2). Mean values having the same small letter within the same column are not significantly different (p<0.05).

Utilization of protein concentrates from rice bran and broken grains (binlid) as encapsulant of β-carotene in model food systems for improved in vitro delivery

FP Flores, MJFA Magnaye, APP Tuaño

Vitamin A is an important micronutrient that affects several biological functions. However, humans cannot synthesize vitamin A so it is obtained from diets. β-carotene has the highest vitamin A activity and is converted most efficiently to vitamin A, but its maximum absorption from natural plant sources is low (~65%). Pure β-carotene is rapidly degraded in the gastric phase during digestion, which means that the delivery vehicle must protect it from initial degradation without inhibiting intestinal release. Encapsulation and entrapment technologies such as coacervation, spray drying and adsorption may stabilize β-carotene with the aim of improving bioavailability. This study focuses on the encapsulation of β-carotene using rice proteins for improved bioavailability and value addition to rice processing by-products.

Activities:

- Optimization of rice bran protein concentrate production by alkali extraction and isoelectric precipitation using various defatting, extraction, and drying conditions
- Determination of the proximate composition of rice bran protein concentrates
- Preparation of β-carotene dispersion using rice bran protein concentrate as stabilizer

Results:

- Optimization of protein extraction protocols from composite rice bran was completed and the method yielding highest protein content was adopted. The rice bran protein concentrate contained 1.3% moisture, 4.6% fat and 64.8% protein. Protein concentrates production from broken grains (binlid) and other analyses are on-going.

- Dispersions containing β-carotene (Figure 24) were prepared and observed to exhibit Tyndall effect. Freeze-drying of dispersions to produce powdered microcapsules is on-going and characterization of the final product will follow.

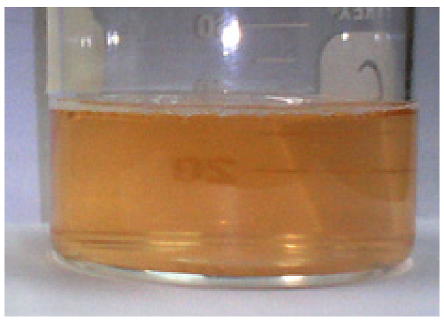

Figure 24. A sample of the prepared β-carotene powder-rice bran protein concentrate dispersion.

Production nanotechnology of rice straw and rice hull for industrial applications
JJMonserate, RPilare, JRSalazar, RMBulata, and MVRomero

Palay (Oryza sativa) is considered as one of the most valuable crop in the Philippines with a total cultivation area of 4.7 million ha and annual production of 18.4 million metric tons (BAS, 2013). As the processing of rice goes on, there are some agricultural by products produced like rice straw and rice hull. Rice straw is basically the stem of the rice plant while the rice hull is the tough covering that surrounds and protects the rice kernel. The most common practice of farmers is to burn rice straw and hull in the open field, but this process imposes a threat especially to the environment as tons of unwanted greenhouse gases are being produced. Rice straw or rice hull can be converted into high valued industrial products such as cellulose acetate and silica, in which through nanotechnology, they can be transformed into a nano scale. With this, the properties of the material change that will suit for industrial applications such as water nano-filtration system, nanoremediation system, biofilm for packaging and industrial catalysts. Studies shows that

47.5% of rice straws are composed of cellulose, hence it proves that it is a good source of cellulose, which is the main component of cellulose acetate (Yang, 2006). Therefore, this study aimed to produce cellulose acetate from rice straw for agricultural and industrial applications. Furthermore, this study also intended to evaluate the feasibility of putting up a local production facility for the production of cellulose acetate from rice straw.

Activities:

- Cellulose acetate (CA) and electrospun nanofiber were produced from rice straw using optimized method. Straw from different rice varieties, namely, PSB Rc10, Rc216, Rc152, Rc238 were delignified to produce CA. Rice straw was boiled in 10% of sodium hydroxide at 55-65°C. Filtrates were washed then bleached with 1% hypocholorite and acetate buffer at pH 5. Straw of different rice varieties were screened for their pulp yield.

- Chemical properties of CA were characterized using Fourier Transform Infrared Spectroscopy.

- Heavy metal removal system was developed by mixing the derived CA with a biodegradable polymer (Polylactic Acid) and alpha ferric oxide nanoparticle.

- Pesticide residue removal system was developed using the synthesized nanoremediation particles.

- Evaluated the efficiency of the pesticide residue removal system to eliminate organic pesticide residues using SEM and ICPMS OR GC-MS.

Results:

- NSIC Rc22 had the highest pulp yield (35.7%) while NSIC Rc152 had the lowest (14.4%) among the samples.

- Rice straw was acetylated by mixing glacial acetic acid, acetic anyhydride, sulfuric acid, and water at 50-65°C. After washing, filtrate were soaked overnight and air-dried. Among the samples, NSIC Rc10 had the highest CA yield (93%) while NSIC Rc216 has the lowest (39.43%). To enhance further the CA yield of rice straw samples, the following solvents were used: sulfuric acid and ionic liquid with sulfuric acid. Among the samples, NSIC Rc10 obtained the highest CA. The solvent combination of sulfuric acid and ionic liquid yielded the highest CA of 4.37g while sulfuric alone yielded only 2.46 grams. The percentage yield of sulfuric acid and ionic liquid with sulfuric acid were 123% and 219%, respectively.

- Fourier transform infrared spectroscopy analysis confirmed the compositional resemblance of the produced CA from rice straw with that of CA standard from Sigma Aldrich (Figure 25). IR spectra of CA showed the presence of carbonyl (C=0) and ester (C-O-C) bands at 1750 cm-1 and 1200 cm-1, respectively. The peaks at 1000-1050 cm-1 (C-O-C asymmetric stretching of pyranose) and 1350 cm-1 (C-H symmetric stretching) showed characteristic peaks of CA, which indicate a good mixing of the polymers.

- CA was electrospinned by dissolving it with poly lactic acid, dicholromethane, and methanol with ratio concentration of 3g: 18ml: 6ml, respectively. CA ratio was tested in different amount from 0.4 to 0.8g. Among the weights tested, 0.5g of CA was the finest. Electrospinning of nanofibers was fabricated at 30kv. Mass production of electrospun nanofiber is being conducted at the Physical, Inorganic and Material Science Laboratory, Department of Chemistry CLSU.

- Heavy metal content of soil samples were determined and their values were compared with those of the regulated level of heavy metal in soil. Results showed that the initial soil sample had exceeded the regulated level of Hg. Also, it contains Cr and Pb which are toxic even in small amount. After nanoremediation, soil analysis revealed that the concentrations of α-Fe2O3 nanoparticle had inverse effect against Hg, Cr, and Pb contens. Among the treatments, 0.5 g of α-Fe2O3 had the most efficient concentration that could lower the toxic concentration of the heavy metal tested. This is due to the magnetic property of the oxidized α-Fe2O3, which resulted to adsorption and degradation of heavy metals.

- Pesticide residue analysis revealed that the soil samples contained high concentration of organochlorine pesticide residues such as Endosulfan II, DDT, Beta BHC, and DDE. There are also trace amounts of Heptachlor epoxide, Methoxychlor, Alpha and Gamma BHC, Aldrin, Chlordane, Endosulfan I, Diedron I, Endrin, TDE, and Metocychlor. After nanoremediation, the concentrations of organochlorine pesticide residues were decreased significantly. This might be due to the reaction of α-Fe2O3 with organochlorine pesticide residues, which disintegrated the product having the same components position with the reactants. Moreover, this was due to the compounds' ability to degrade the bonds existing

between organochlorine pesticide residues.

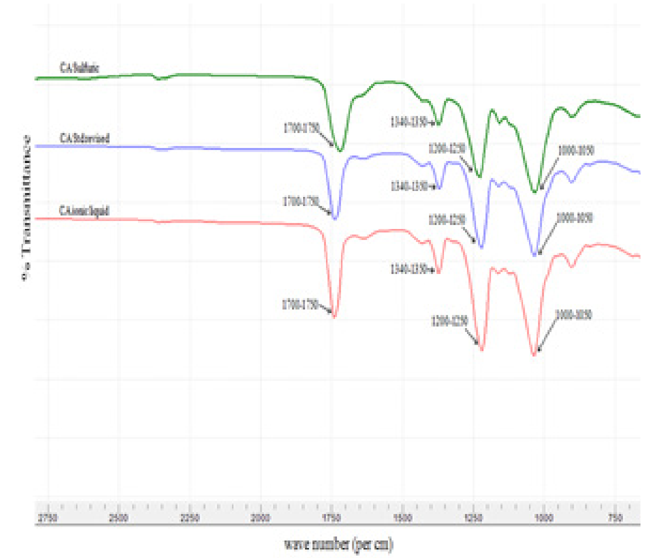

Figure 24. Spectral analysis of cellulose acetate.

Abbreviations and acronymns

ABA – Abscicic acid
Ac – anther culture
AC – amylose content
AESA – Agro-ecosystems Analysis
AEW – agricultural extension workers
AG – anaerobic germination
AIS – Agricultural Information System
ANOVA – analysis of variance
AON – advance observation nursery
AT – agricultural technologist
AYT – advanced yield trial
BCA – biological control agent
BLB – bacterial leaf blight
BLS – bacterial leaf streak
BPH – brown planthopper
Bo - boron
BR – brown rice
BSWM – Bureau of Soils and Water Management
Ca - Calcium
CARP – Comprehensive Agrarian Reform Program
cav – cavan, usually 50 kg
CBFM – community-based forestry management
CLSU – Central Luzon State University
cm – centimeter
CMS – cystoplasmic male sterile
CP – protein content
CRH – carbonized rice hull
CTRHC – continuous-type rice hull carbonizer
CT – conventional tillage
Cu – copper
DA – Department of Agriculture
DA-RFU – Department of Agriculture-Regional Field Units
DAE – days after emergence
DAS – days after seeding
DAT – days after transplanting
DBMS – database management system
DDTK – disease diagnostic tool kit
DENR – Department of Environment and Natural Resources
DH L– double haploid lines
DRR – drought recovery rate
DS – dry season
DSA - diversity and stress adaptation
DSR – direct seeded rice
DUST – distinctness, uniformity and stability trial
DWSR – direct wet-seeded rice
EGS – early generation screening
EH – early heading
EMBI – effective microorganism-based inoculant
EPI – early panicle initiation
ET – early tillering
FAO – Food and Agriculture Organization
Fe – Iron
FFA – free fatty acid
FFP – farmer's fertilizer practice
FFS – farmers' field school
FGD – focus group discussion
FI – farmer innovator
FSSP – Food Staples Self-sufficiency Plan
g – gram
GAS – golden apple snail
GC – gel consistency
GIS – geographic information system
GHG – greenhouse gas
GLH – green leafhopper
GPS – global positioning system
GQ – grain quality
GUI – graphical user interface
GWS – genomwide selection
GYT – general yield trial
h – hour
ha – hectare
HIP - high inorganic phosphate
HPL – hybrid parental line
I - intermediate
ICIS – International Crop Information System
ICT – information and communication technology
IMO – indigenous microorganism
IF – inorganic fertilizer
INGER - International Network for Genetic Evaluation of Rice
IP – insect pest
IPDTK – insect pest diagnostic tool kit
IPM – Integrated Pest Management
IRRI – International Rice Research Institute
IVC – in vitro culture
IVM – in vitro mutagenesis
IWM – integrated weed management
JICA – Japan International Cooperation Agency
K – potassium
kg – kilogram
KP – knowledge product
KSL – knowledge sharing and learning
LCC – leaf color chart
LDIS – low-cost drip irrigation system
LeD – leaf drying
LeR – leaf rolling
lpa – low phytic acid
LGU – local government unit
LSTD – location specific technology development
m – meter
MAS – marker-assisted selection
MAT – Multi-Adaption Trial
MC – moisture content
MDDST – modified dry direct seeding technique
MET – multi-environment trial
MFE – male fertile environment
MLM – mixed-effects linear model
Mg – magnesium
Mn – Manganese
MDDST – Modified Dry Direct Seeding Technique
MOET – minus one element technique
MR – moderately resistant
MRT – Mobile Rice TeknoKlinik
MSE – male-sterile environment
MT – minimum tillage
mtha^{-1} - metric ton per hectare
MYT – multi-location yield trials
N – nitrogen
NAFC – National Agricultural and Fishery Council
NBS – narrow brown spot
NCT – National Cooperative Testing
NFA – National Food Authority
NGO – non-government organization
NE – natural enemies
NIL – near isogenic line
NM – Nutrient Manager
NOPT – Nutrient Omission Plot Technique
NR – new reagent
NSIC – National Seed Industry Council
NSQCS – National Seed Quality Control Services
OF – organic fertilizer
OFT – on-farm trial
OM – organic matter
ON – observational nursery
OPAg – Office of Provincial Agriculturist
OpAPA – Open Academy for Philippine Agriculture
P – phosphorus
PA – phytic acid
PCR – Polymerase chain reaction
PDW – plant dry weight
PF – participating farmer
PFS – PalayCheck field school
PhilRice – Philippine Rice Research Institute
PhilSCAT – Philippine-Sino Center for Agricultural Technology
PHilMech – Philippine Center for Postharvest Development and Mechanization
PCA – principal component analysis
PI – panicle initiation
PN – pedigree nursery
PRKB – Pinoy Rice Knowledge Bank
PTD – participatory technology development
PYT – preliminary yield trial
QTL – quantitative trait loci
R - resistant
RBB – rice black bug
RCBD – randomized complete block design
RDI – regulated deficit irrigation
RF – rainfed
RP – resource person
RPM – revolution per minute
RQCS – Rice Quality Classification Software
RS4D – Rice Science for Development
RSO – rice sufficiency officer
RFL – Rainfed lowland
RTV – rice tungro virus
RTWG – Rice Technical Working Group
S – sulfur
SACLOB – Sealed Storage Enclosure for Rice Seeds
SALT – Sloping Agricultural Land Technology
SB – sheath blight
SFR – small farm reservoir
SME – small-medium enterprise
SMS – short message service
SN – source nursery
SSNM – site-specific nutrient management
SSR – simple sequence repeat
STK – soil test kit
STR – sequence tandem repeat
SV – seedling vigor
t – ton
TCN – testcross nursery
TCP – technical cooperation project
TGMS – thermo-sensitive genetic male sterile
TN – testcross nursery
TOT – training of trainers
TPR – transplanted rice
TRV – traditional variety
TSS – total soluble solid
UEM – ultra-early maturing
UPLB – University of the Philippines Los Baños
VSU – Visayas State University
WBPH – white-backed planthopper
WEPP – water erosion prediction project
WHC – water holding capacity
WHO – World Health Organization
WS – wet season
WT – weed tolerance
YA – yield advantage
Zn – zinc
ZT – zero tillage

List of Tables

List of Tables

List of Figures

List of Figures

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